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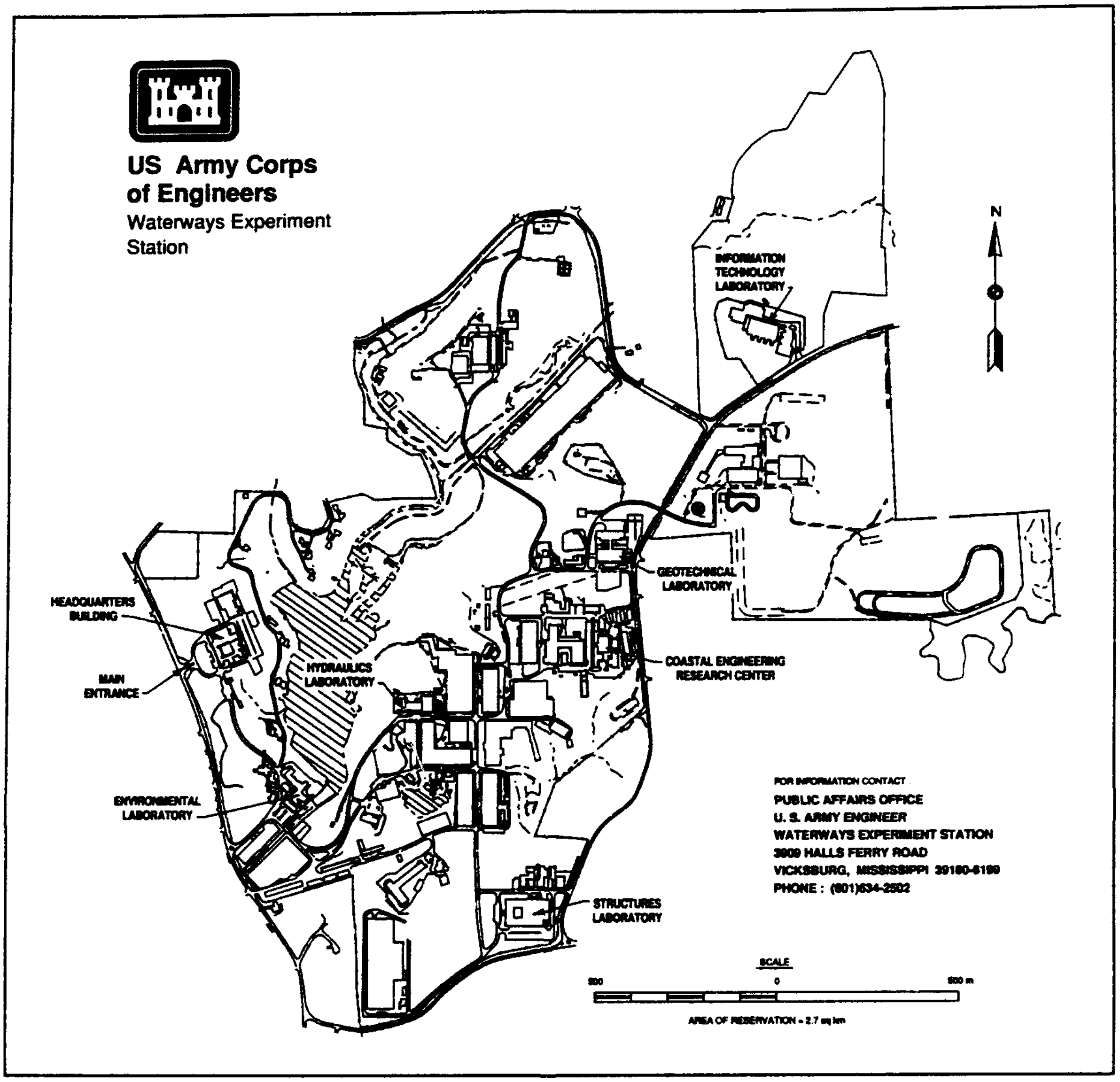

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[1] Plates 1-5 are located in the pocket of the back cover.

Preface

A waterborne seismic reflection investigation was conducted in the Inner Bar Channel and Anchorage Basin near Galveston, Texas, by personnel of the Geotechnical and Hydraulics Laboratories (GL, HL), U.S. Army Engineer Waterways Experiment Station (WES), during the period 14-17 July 1992. The investigation was performed under sponsorship of the U.S. Army Engineer District, Galveston (CESWG). The CESWG Project Engineer was Mr. Neil McClellan.

The overall test program was conducted under the general supervision of Drs. W. F. Marcuson III, Director, GL, and A. G. Franklin, Chief, Earthquake Engineering and Geosciences Division (EEGD). Mr. Keith J. Sjostrom was the Principal Investigator. This project is a cooperative effort with the Hydraulics Laboratory under the supervision of Drs. F. A. Herrmann, Director, HL, and G. A. Pickering, Chief, Hydraulics Structures Division (HSD). This report was prepared by Mr. Sjostrom under the supervision of Mr. J. R. Curro, Jr., Chief, Engineering Geophysics Branch, GL, and Mr. Richard G. McGee under the supervision of Dr. B. J. Brown, Chief, Hydraulic Analysis Branch, HL. Instrumentation support was provided by Mr. Tom S. Harmon, Jr., EEGD, GL. Data collection and analysis assistance during this study were provided by Messrs. Rodney L. Leist and Jeff S. Zawila, EEGD, GL, and by Ms. Janie M. Vaughn, HSD, HL.

Acknowledgement is made to the personnel of the Engineering Design Section and Surveys Section, CESWG, for their assistance during this study. The crew of the survey vessel 'Vollert' is especially appreciated for its support in performing the field surveys. Subbottom sediment sampling and analysis were performed by personnel of Rice University.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
cubic yards	0.7645549	cubic meters
feet	0.3048	meters

1 Introduction

Background

At the request of the U.S. Army Engineer District, Galveston (CESWG), the U.S. Army Engineer Waterways Experiment Station (WES) conducted a waterborne seismic reflection survey of the Inner Bar Channel and Anchorage Basin near Galveston, Texas (see Figure 1). These two areas are part of the Gulf of Mexico entrance to the Houston Ship Channel and allow ocean-going traffic access to the port of Houston and other facilities along Galveston Bay. The resultant information from this investigation will be used in the development of plans and specifications for maintenance dredging of the project area. A description of the bottom and subbottom materials to be dredged in terms of density and soil classification are necessary for planning and monitoring the dredging program.

Purpose and Scope

The objective of the study is to quantify, as a function of depth, the bottom and subbottom sediments in terms of density and soil type to elevation -50 ft Mean Low Tide (MLT) beginning at station 5+000 of the Inner Bar Channel and ending at station 22+000. This also includes the entire Anchorage Basin (see Figure 2). The results are intended to supplement previously obtained soil borings by providing continuous profile line coverage along the length of the project area and aid in placement of any additional soil borings that may be required. The processed seismic data will also provide: (1) material density and soil classification information of sediments within the channel and anchorage area, (2) better descriptions of changes in the actual subbottom conditions, (3) volumetric determination of the amount of sandy material available for beneficial use in the Inner Bar Channel, and (4) location of other areas having predominantly sandy material on the bottom surface. Two high resolution subbottom profiling systems and a specially designed data acquisition and analysis software package were used to meet the primary objectives of the investigation.

Overview of Site Geology

Near-surface sediments within the project area consist mainly of unconsolidated and partly consolidated flood, tidal, delta, and bay sediments deposited during the early Holocene period. These sediments are comprised of material ranging from silty clays to sandy silts, interbedded layers of sand and mud, and unconsolidated to moderately stiff clays. More recent sandy tidal delta and inlet deposits that once overlayed these relic sediments have apparently been removed through dredging efforts. Sandy material, however, is still being deposited into the Inner Bar Channel and Anchorage Basin by tidal cycles and wave transport and must be routinely removed from the project area through dredging. Areas of shells are also routinely present in the near-surface sediments.

The site is underlain by compacted, stiff floodplain clays and silts of Pleistocene age. Borings indicate the consistencies of the fine-grained sediments range from stiff to hard and may be characterized by an increase in blow counts. Relic stream channels and terraces may also cut into the Pleistocene sediments. The paleochannels may be infilled with less dense clayey material or sand and gravel deposits. Additional information about the geology of Galveston Bay is described in Fisher et al. (1972).

2 Technical Approach

Seismic Reflection Principles

Acoustic subbottom reflection data are produced when a source of acoustic energy is deployed just below the water surface. When acoustic energy generated from the deployed source arrives at a boundary between two layers of differing material properties, part of the energy will be reflected back towards the surface and part transmitted downward. Portions of the transmitted energy will undergo absorption or attenuation in the material while the remainder propagates through to the next stratigraphic boundary. Ratios between transmitted and reflected energy, called reflection coefficients, are dependent on the density and velocity of the materials through which the energy is propagating. The acoustic reflection coefficient (R) is defined as:

$$R = \sqrt{\frac{E_R}{E_I}}$$

where E_R is the reflected energy and E_I the total energy incident to the stratigraphic boundary.

The reflection coefficient may also be expressed in terms of impedance, Z, using the following equation

$$R = \frac{(Z_s - Z_w)}{(Z_s + Z_w)}$$

where the acoustic impedance of a sediment is defined as the product of the material density (ρ_s) and transmission velocity (C_s) and represents the influence of the material's characteristics on reflected and transmitted wave energy. Specifically,

$Z_w = \rho_w C_w$ = water impedance
$Z_s = \rho_s C_s$ = sediment impedance

and

$\rho_w = 1.0 \text{ g/cm}^3$
$C_w = 1.5 \times 10^5 \text{ cm/sec}$

Substituting, the impedance of the subbottom sediments may be determined from measured ratios of the transmitted and reflected wave energy.

$$\sqrt{\frac{E_R}{E_I}} = \frac{(Z_s - Z_w)}{(Z_s + Z_w)}$$

The relationship between acoustic impedance and specific soil properties has been empirically based on an extensive database of world averages of impedance versus sediment characteristics (Hamilton 1970, 1972; Hamilton and Bachman 1982). These relationships, however, are based primarily on surficial marine sediments. In order to extend the depth of investigation into multi-layer subbottom environments, Caulfield and Yim (1983) devised a geoacoustic model correlating Hamilton's work. The model is used to correct for absorption and transmission losses in the subbottom sediments as a function of frequency such that the reflection coefficients and impedance values may be calculated as if they were surficial sediments. The concept is extended to each subsequent layer until the signal-to-noise ratio is at a level where information cannot be extracted with accuracy. The model is then combined with classical multi-layer reflection analysis algorithms to yield acoustic impedance values equivalent to surficial sediments for subbottom layers. The calculated values are compared to the database developed by Hamilton to categorically classify each detected sediment regime.

Seismic Reflection Survey Approach

The energy sources used to acquire the acoustic subbottom reflection records are a 3.5 kiloHertz (kHz) high resolution 'pinger' system and an integrated, high definition 400 Hz to 5.0 kHz 'boomer' system. In general, higher operating frequencies permit greater resolution of the marine sediments but shallower depths of energy penetration depending on the characteristics of the subbottom material. The sources of acoustic energy are deployed just below the water surface and generate acoustic waves that propagate downward through the water column and sediments. As the transmitted energy propagates through sediment of varying densities and acoustic velocities, energy is reflected at geologic boundaries where there is a distinct contrast in the acoustic impedance between the layers. Reflected signals are detected, amplified, filtered, and recorded with a shallow seismic, digital data acquisition system. Acoustic data collected are acquired in near real-time to permit continual data quality control. Signals from both the 'boomer' and 'pinger' systems are also printed in an analog format.

Seismic reflection signatures are most often nonunique and therefore several combinations of geologic conditions could conceivably yield similar signal

characteristics and computed impedance values. But in specific geologic regions such as Galveston Bay, differing sediment units have a characteristic range of impedance values. Therefore, using calibration procedures incorporating local core data, the reflection data are corrected for transmission and absorption losses and processed to yield acoustic impedance values at reflection horizons. Estimates of material density are derived from the computed impedance through geoacoustic modeling procedures developed by Caulfield (1983) and Hamilton (1980). The computed density results are correlated with ground truth information for verification. This specific technique is also described by McGee and Ballard (1992). Through additional processing, the results are adjusted to the Mean Low Tide (MLT) datum by removing tidal fluctuations and correlated with survey vessel positioning data.

The virtually continuous linear data coverage of the subbottom material are presented in amplitude cross-sections which illustrate the different reflection horizons in the subbottom. Incorporating the corrected depths, positioning information, and the computed sediment densities or material types, two-dimensional (2-D) profiles of the sediment distribution versus location are produced to assist the project engineer in assessing the subbottom characteristics throughout the project area. These plots also assist in placement of additional sample locations to directly investigate the sediment characteristics at the site. The computed density information of the subbottom sediments may also be incorporated into a terrain modeling software package to produce a three-dimensional (3-D) view of the sediment distribution. The displays are color-coded according to sediment density to highlight material density zones. Three-dimensional visualization also permits volumetric calculation of the differing sediment units within the study area.

Geophysical Survey

A map showing the location of the geophysical survey lines along the Inner Bar Channel and Anchorage Basin are presented in Figures 3 and 4, respectively. The survey layout of each area is described below.

Inner Bar Channel

The Inner Bar Channel (Figure 3) begins at station 5+000 and extends 17,000 ft to station 22+000, the beginning of the Outer Bar Channel. The survey consists of seven profile lines labelled IP01 through IP07. One survey, profile IP06, is conducted along the center line of the channel and the remaining lines are positioned at distances of 150, 250, and 350 ft along either side of the center line. The outermost surveys at 350 ft are also 50 ft off the toe or edge of the channel.

Anchorage Basin

The Anchorage Basin (Figure 4) begins near station 12+000 and extends 11,400 ft to station 23+400 along the Outer Bar Channel. The survey in this trapezoidally shaped area consists of twelve profile lines conducted parallel to the Inner Bar Channel. The surveys are denoted as lines AP01 through AP12 and range in length from 4,000 to 11,400 ft. The profiles are spaced 250 ft apart with the first survey line located approximately 100 ft from the north toe of the Inner Bar Channel.

Survey Methodology

The high-resolution 'pinger' system was mounted on the hull of the survey vessel and used as the primary investigative tool. The 'pinger' provides good resolution of the multi-layer geology in each area to the required depth of investigation. The source/receiver separation was 10 ft and each set of transducers were positioned approximately three feet below the water surface. The 'pinger' was operated at a tuned frequency of 3.5 kHz and a total trace length of 700 samples were selected during data collection. A digital acquisition sampling rate of 52 microseconds was used for data collected within the Inner Bar Channel whereby limiting the depth of subsurface exploration to approximately 90 ft below the water surface. Data were collected in the Anchorage Basin using a sampling rate of 32 micro-seconds resulting in a depth of investigation of approximately 60 ft. A high definition 'boomer' system was also towed behind the survey vessel during the investigation. However, the 'boomer' data was of poor quality and therefore not used in the data analysis.

Navigational and positioning support was provided by CESWG personnel. Positioning information for each survey line was recorded during seismic data acquisition and correlated to the geophysical records with respect to time. CESWG also provided precision bathymetric data referenced to Mean Low Tide. Bottom depths for the subbottom profiles are adjusted to the CESWG depth measurements since the data provides nearly a 10:1 improvement in resolution over any of the subbottom equipment.

3 Subbottom Sediment Sampling

During past stages of proposed maintenance dredging work, the CESWG has conducted exploratory boring programs in both the Inner Bar Channel and Anchorage Basin. An additional ten cores were collected following the geophysical survey to more accurately calibrate to geoacoustic model and develop the necessary acoustic parameters to derive estimates of bottom and subbottom material density. The WES core locations, shown in Figure 5, were positioned in areas of the project having differing seismic signatures as indicated on the seismic reflection field records. The WES cores are denoted as 'CERC-#' where '#' indicates the core number.

Shallow penetration coring was performed by Rice University personnel (under contract with CESWG) using vibracore techniques and a free-fall piston sampler. Sediment sample analysis was performed by Rice University and a short summary of the results are shown in Table 1. The lab analysis was designed to determine the parameters that most directly affect the propagation of an acoustic wave in submarine environments; i.e., density, porosity, mean grain size, and soil gradation. Sediment penetration was limited in a number of areas due to the dense, compacted nature of the subbottom materials. The length of the core samples (see Table 1) ranged from one to six feet with an average length of two feet. A full letter report documenting the core sample acquisition and analysis was sent to CESWG by Rice University.

Existing cores completed and analyzed by CESWG were also used during this investigation (see Figure 5). These cores are denoted by the label '3ST-##', where '##' represents the core number, and were completed to an elevation range of -50 to -55 ft MLT. A short summary of the sediment analysis for cores 3ST-83 through 3ST-91 are presented in Table 2. Laboratory analysis information provided to WES for cores 3ST-24 to 3ST-39 was limited to representative soil classification at 2.5 ft intervals. Each of the CESWG cores were drilled in 1966.

4 Data Calibration and Ground Truth Correlation

Using calibration procedures for data with high signal to noise ratios, seismic reflection data are processed to provide estimates of the density and soil type of bottom and subbottom sediments. Calibrations are performed by correlating acoustic impedance values calculated from the seismic reflection data at a sample location with the measured information (density, mean grain size, etc.) at that location. Experience to date has shown that calibrations made at a few locations within in a geologic region provides the necessary shallow seismic parameters to accurately calibrate and describe the entire region (McGee 1991). Calibration of the acoustic reflection data for the Inner Bar Channel and Anchorage Basin are briefly described in following paragraphs.

Bottom Sediment (Surface) Calibration

The first calibration procedure performed with the reflection data determines the total energy incident at the bottom surface. This process involves determining the precise reflection coefficient for the first reflector (bottom surface) and the associated acoustic bottom loss for the given sediment. The surface calibration begins by determining the total energy produced by the acoustic energy source from the direct wave and the transmission losses associated with underwater acoustic wave propagation. These parameters are evaluated using the sonar equation. For an in depth discussion of the sonar equation, refer to Urick (1983). The computed source energy and transmission losses are in turn used to calculate the surface reflection coefficients. The reflection coefficients and bottom loss are then correlated with the measured sediment properties (density, mean grain size, water content, etc.) to calibrate the bottom surface materials. Surface calibrations were conducted at WES cores CERC-4 in the Anchorage Basin and CERC-8 in the Inner Bar Channel. Both cores are approximately two feet in length. Analysis of core CERC-4 revealed thin, alternating zones of fine sand and mud with a measured density range of 1.57 to 1.86 g/cm^3. Computed sediment densities incorporating the calibration parameters indicate a density range of 1.53 to 1.76 g/cm^3. Analysis of core CERC-8 indicated a layer of fine sand over interbedded layers of sand and mud. This material has a laboratory measured

density range of 1.63 to 1.85 g/cm^3. Computed density estimates incorporating the calibration parameters ranged from 1.70 to 1.85 g/cm^3. The acoustically derived density estimates using the calibration parameters versus the measured characteristics of cores CERC-4 and CERC-8 are illustrated in Figures 6 and 7, respectively.

Calibration locations may be thought of as acoustic cores taken at various locations within the project area. The calibration plots shown in Figures 6 through 17 illustrate the acoustically derived density values versus depth at a core location in which directly measured density values exist. Referring to Figure 7, a portion of the seismic reflection record taken at WES core location CERC-8 is presented in the leftmost block entitled 'Acoustic Reflection Record'. The darker colors represent higher amplitude signals recorded from the varying geologic interfaces. The bottom surface is detected at an elevation -41 ft MLT and a second distinct interface, where a change in impedance exists, is measured at elevation -57 ft MLT. Using surface and subbottom sediment calibration parameters, impedance values are computed for that portion of the seismic record and displayed in the block labelled 'Acoustic Impedance Record'. The impedance values are color-coded such that the darker colors are related to higher impedance values. Using the impedance versus sediment database developed by Hamilton, the higher impedance values are related to more competent sediments having higher density values such as a sand or stiff clay. In the block entitled 'Density', the solid line depicts the acoustically derived density values versus depth as related to the impedance versus density database. The black dots represent measured density values at specific depths for the core indicated in the title block. Visual sediment classification from the driller's log is outlined in the block titled 'Lithology'.

In areas where no core information exists, the calibration plot may be used as an acoustic core at a specific location. A portion of the acoustic amplitude record at an area of interest may illustrate representative seismic signatures of the bottom and subbottom geology or depict a change in the bottom and subbottom geologic conditions. Using the calibration parameters for the project area, the acoustically derived impedance and density values are computed and displayed to assist in the geologic interpretation of the site.

Subbottom Sediment Calibration

The second part of the calibration adjusts the impedance function for effects of acoustic absorption in unique soil types as the acoustic wave is propagated down and reflected back through the subbottom. Estimates of acoustic absorption, or the attenuation coefficient, are computed from reflection data only in areas where a multi-layered lithology exists. It should be noted that when only a surface reflection exists, the surface calibration is all that is necessary. The attenuation coefficients are initially correlated to empirical geoacoustic relationships developed to describe the characteristics of bottom and subbottom sediments (Hamilton 1980; Caulfield 1983). These results are compared to core information and any precision adjustments

necessary are made in the acoustic analysis parameters to obtain the best possible correlation.

None of the WES cores collected extend deep enough into the subsurface to provide a distinct change in lithology such as the interface between the silty material and stiff clay. Therefore, the initial subbottom calibration was accomplished at CESWG cores 3ST-85 and 3ST-87. WES core CERC-3 is located near core 3ST-87. Core analysis indicated sandy silty clay overlying a layer of compacted (stiff) clay. The sandy silty clay has an approximate density of 1.6 g/cm^3 as measured from core CERC-3. Figures 8 and 9 present the acoustically derived density estimates versus the laboratory determined values for cores 3ST-85 and 3ST-87, respectively. Each density versus depth prediction illustrates increasing densities near the interface with the compacted clay material as one might expect.

Check Calibrations

To verify the assumption of regional calibrations, numerous check sites were also evaluated. Acoustically derived estimates were compared with core samples taken throughout the project area using the final acoustic parameters established from the surface and subbottom calibrations. Check calibrations were performed at the following core locations: 3ST-29, CERC-7, CERC-6, CERC-9, 3ST-32, CERC-5, 3ST-86, and CERC-2. The results are illustrated in Figures 10 through 17, respectively. Where measured sediment density values are available, the acoustically derived estimates demonstrate good correlation. Typically, the computed densities deviate about the measured values by approximately ± 0.2 g/cm^3 or 10 percent of the computed result.

5 Data Analysis and Results

Data Analysis

Continuous subbottom profiles of the acoustic reflection amplitudes obtained using the high resolution 'pinger' system for surveys performed in the Inner Bar Channel and Anchorage Basin were delivered to the CESWG Project Engineer in August 1992. The records are annotated with CESWG core locations and channel stationing. Positioning and bottom depth information for each survey line are presented in Appendices A and B for Inner Bar Channel and Anchorage Basin surveys, respectively. Correlating the information interpreted from the seismic amplitude records with existing core information, a general description of the subbottom sediments and material density distributions are provided for each area of the survey.

Limitations and boundary conditions

Before discussing the density results of the Inner Bar Channel and Anchorage Basin investigation, a few comments are needed regarding interpretation of acoustically derived estimates. These topics are addressed as follows.

Accuracy. The density predictions are calculated from data collected by a remote sensing technique and should not be considered absolute measurements of density. However, computed density values should safely fall within 10 percent of directly determined values. Due to the shallow cores obtained by Rice University, ground truth verification of the density estimates were limited to upper 1 to 5 ft of sediment. The absorption model used to estimate the density of deeper materials may produce values somewhat lower than insitu. Also, ground truth information from older cores was not available below elevation -52.5 ft MLT.

Impedance function. The impedance function used for this technique is based on empirical data collected from primarily deeper offshore environments in naturally occurring marine sediments (Caulfield 1983). Therefore, this algorithm may produce anomalous density values and estimates in the dynamic near-shore, harbor, and riverine environments. Compacted sediments or highly active organic soils could compute as something they are not; hence, one of the primary reasons for the regional calibration approach.

In the Inner Bar Channel and Anchorage Basin, many of the core samples contained shell fragments; a common occurrence in this coastal environment. These fragments may cause strong acoustic reflectors which would in turn compute as material more competent than the primary sediment in the sample.

Correlation between acoustic profiles and core logs. The acoustically derived sediment profiles are cross-referenced to the core locations in each project area. Many of these cores are not located precisely on a survey line. Therefore, surface conditions may vary somewhat due to maintenance dredging, construction activities, or isolated surface anomalies which may produce apparent discrepancies between the reflection data and cores.

Density estimates and soil classification

The bottom and subbottom sediment analysis within the project area emphasizes density distribution with respect to lateral extent and depth. Density ranges used for data presentation were provided by CESWG personnel to more practically delineate the sediment distribution and better assess the difficulty of removing these material through dredging operations. The computed density values are related to a basic soil description, based on the database for natural, undisturbed marine sediments, as shown in Table 3. The relationships are valid for the sampled locations in the project area except for areas where anomalous marine sediment conditions are detected. The associated color-code is used to highlight the density ranges presented on the color profiles described later in the report.

Data presentation

In general, the density zones established delineate the predominantly clay, silt, and sand regions within the area surveyed. The distributions of computed sediment densities within the project area are presented in Plates 1 through 5 as 2-D profiles illustrating the primary subbottom interfaces and differing zones of sediment material. The profiles illustrate the depth to a particular interface (in feet MLT), representative sediment density, and corresponding station location along the survey line. Completed CESWG and WES cores are also identified. The labelled black dots at the top of each profile denote the survey track line and direction. Each dot also represents the beginning of every third seismic data file recorded in order to give an indication of the data coverage along each survey line and assist in correlating the raw data and interpreted results. The associated label represents the data file number. Appendices A and B present the location, tidal information, and bottom elevation in feet MLT for the appropriate data file number along each survey line in the Inner Bar Channel and Anchorage Basin, respectively. The 2-D profiles, as presented on Plates 1 through 5, are aligned such that if a person were positioned on the south toe of the Inner Bar Channel and looking north, the interpreted results would appear in consecutive order across the project area. The Gulf of Mexico would be towards the right side of the diagrams.

The computed density values in the Inner Bar Channel and Anchorage Basin are also incorporated into a terrain modeling software package. Computed density values are spatial averaged with respect to lateral distance and depth to produce a three-dimensional (3-D) representation of the sediment density distribution across the project area. Color-coded 2-D profiles are extracted from the 3-D density representation along each survey line. These views illustrate the density distribution both laterally and with depth along a profile line. The displays have color-coded density increments of 0.20 g/cm^3 to enhance the density gradations within each zone. This form of data presentation should not be used for detailed analysis of the project area.

Results

Inner Bar Channel

The Inner Bar Channel extends from station 5+000 to station 22+000 (see Figure 2). Seven seismic reflection surveys, lines IP01 through IP07, were performed in the channel and the 2-D cross-sections illustrating the different sediment regimes and density distributions are shown in Plates 1 and 2. The interpretations for surveys IP01, IP03, and IP06, the channel centerline, are presented on Plate 1 and surveys IP04, IP05, and IP07 are shown on Plate 2. The data quality along survey line IP02 was poor and, therefore, no interpretation or acoustic analysis was performed. Existing CESWG and WES core locations and appropriate density information where available are also displayed. High quality seismic data was recorded for interpretation purposes to an elevation range of -60 to -70 ft MLT.

The bottom sediments are primarily comprised of materials having densities in the range of 1.6 to 1.8 g/cm^3; indicative of sediments ranging from sandy silty clay to silty sand. Near-surface information from cores collected along the channel, many on the edge of the channel, correlate well with these results. A majority of the cores also indicate layers of moderate to stiff clay which may also typically fall in the same density range. A portion of the seismic record collected along the channel centerline (survey IP06) is shown in Figure 18. Areas of sediments of lesser density (1.4 to 1.6 g/cm^3), indicative of silty clays, exist along the eastern half of survey IP07 and in the extreme eastern and southwestern parts of the channel. Below an elevation of -55 ft MLT, the subbottom sediments typically range in density from 1.4 to 1.7 g/cm^3 and indicative of more clayey material. The distinct interface of the compacted, stiff clay detected in the Anchorage Basin (discussed later in report) is not as prominent in the Inner Bar Channel. This effect may be due to greater percentages of sandy material in the upper sediments that may mask the reflector or the sediment properties of the clay have been disturbed through routine maintenance dredging; thereby lessening the material density.

An extensive area of more dense material is detected along survey line IP01, conducted along the south toe of the channel, and IP03 between stations 10+000 and 18+000. The computed densities are greater than

1.8 g/cm^3. Cores taken within this area indicate a layer of fine sand present on the bottom surface which correlates well with the acoustic results. According to CESWG personnel, the presence of this sandy material is due to shoaling that routinely occurs along this side of the channel. A portion of the seismic amplitude record collected near station 16+500 along line IP01 illustrates the strong reflection due to the sandy material (see Figure 19). A smaller zone of sandy material was also detected at the surface along lines IP05 and IP07 between stations 5+000 and 5+500.

Two-dimensional, color-coded profile displays for lines IP01 through IP07 (excluding IP02) are also shown in Figures 20 through 22. These figures are generated using a statistically based, terrain modeling software package incorporating the density results computed during the project survey. The density range corresponding to each color-code is presented in Table 3. It should be noted that the horizontal distance scale associated with each display represents the distance along the survey line in the direction the survey was performed and *not* CESWG stationing. The computer generated presentations correlate well with the 2-D cross-sections illustrated in Plates 1 and 2. The sandy material detected along lines IP01 and IP03 near the south toe of the channel and in the extreme northwestern end of the channel (line IP07) are depicted by the blue zones in Figures 20 and 22. The majority of the subbottom sediment material is in the density range 1.4 to 1.8 g/cm^3 represented by the red and green colors which correlates well with the directly measured sediment densities.

Anchorage Basin

The Anchorage Basin extends from station 12+000 to 23+400 using the CESWG station designation and parallels the Inner Bar Channel (see Figure 2). Twelve seismic reflection surveys, lines AP01 through AP12, were performed in the Anchorage Basin and the 2-D cross-sections illustrating the different sediment regimes and density distributions are shown in Plates 3 through 5. The results from seismic surveys AP01 through AP03 are displayed on Plate 3, lines AP04 through AP06 on Plate 4, and surveys AP07 through AP12 on Plate 5. The existing CESWG and WES core locations and appropriate density information where available are also displayed. High quality seismic data was recorded for interpretation and density determination purposes to an elevation range of -55 to -57.5 ft MLT.

The acoustically derived results indicate that the upper layer of material extending down to an elevation of approximately -50 ft MLT ranges in density from 1.4 to 1.8 g/cm^3. Material classification determined from the computed densities is clayey silt to silty sand which is consistent with information obtained from CESWG and WES core locations. The thickness ranges from 5 to 12 ft in the southern part of the Anchorage Basin and increases to over 15 ft in the northern extents (see Plates 3, 4, and 5).

Underlying the near-surface material, the sediments transition into a compacted, stiff clay as detected in all but one of the CESWG cores. The

acoustically computed density ranges from 1.8 to 2.3 g/cm^3. The interface pertaining to the stiff clay is indicated on the 2-D interpretations for survey lines AP01 through AP08. A portion of the seismic reflection record collected along survey line AP05 near station 16+500 is presented in Figure 23. The interface is clearly visible at an elevation of -49 ft MLT. A pocket of silty material was detected extending below the compacted clay interface near station 18+000 along survey line AP06. Beginning near stations 17+000 along survey line AP07 and 15+500 along line AP08, the distinct stiff clay interface begins to diminish (see Figure 24) towards the north and east. The computed material density below elevation -50 ft MLT beyond these points decreases to the range of 1.6 to 1.8 g/cm^3. Additional sediment interfaces are also detected within the subbottom along survey lines AP08 through AP12.

Areas of sandy material in the northwest corner of the Anchorage Basin exist at the bottom surface as noted along lines AP09 through AP12 near Station 14+000. The computed density of this material ranges from 1.8 to 2.2 g/cm^3. The thickness of this material, however, could not be resolved. The sandy material is likely a thin veneer overlying the typical silty material found in this area. CESWG personnel stated that sandy material typically settles in this area between periods of maintenance dredging. A portion of the seismic record collected along survey line AP11 near station 14+000 is shown in Figure 25 and illustrates the seismic reflection amplitudes due to the sandy material. No other areas of sandy material were found in the Anchorage Basin.

Two-dimensional, color-coded profile displays for lines AP01 through AP12 are also shown in Figures 26 through 31. These figures are generated using a statistically based, terrain modeling software package incorporating all of the density results computed during the project survey. The density range corresponding to each color-code is presented in Table 3. It should be noted that the horizontal distance scale associated with each display represents the distance along the survey line in the direction the survey was performed and *not* CESWG stationing. The computer generated presentations correlate well with the 2-D cross-sections illustrated in Plates 3 through 5. The interpreted stiff clay layer having high density values detected along lines AP01 through AP07 is represented by the blue zone at elevations -50 to -55 ft MLT (see Figures 26 through 29). The sandy material detected in the northwest corner of the Anchorage Basin is depicted by the blue zone along lines AP09 through AP12 (Figures 30 and 31). Otherwise, the majority of the near-surface material is in the density range 1.2 to 1.8 g/cm^3 represented by the orange, red, and green colors.

Volumetric Estimates

One of the project objectives is the volumetric determination of the amount of sandy material in the Inner Bar Channel that may be dredged and used beneficially elsewhere. According to the CESWG project engineer, coarser grained sediments are routinely deposited along the southern side of the

channel (outbound lane) because of shoaling, tidal deposition, and wave transport. During the seismic investigation, sandy material was readily detected and interpreted along this reach of the channel (see Plate 1). Volumetric estimates are computed from results obtained along survey lines IP01, IP03, and IP06, which cover the outbound lane of the Inner Bar Channel, using the 2-D and 3-D density distribution displays. The interpreted thickness of sandy material above the set dredging limit of -45 ft MLT is measured along each of the three survey lines and correlated to the surface area of the project site. The total volume of material to be removed through dredging is computed at 850,000 yd^3. Incorporating the acoustically derived density information for these sediments, the total quantity of sandy material available is in the range of 500,000 to 540,000 yd^3. It is noted that approximately 160,000 yd^3 of this volumetric range are considered poorly graded, clean sands having a medium to coarse grain size. This is the most extensive area of sandy material within the project scope. Other much smaller areas, located as noted earlier in the report, were not included in the volumetric estimation.

6 Project Summary

A high-resolution, seismic reflection survey was performed in the Inner Bar Channel and Anchorage Basin near Galveston, TX to quantify the densities and soil types of the near-surface marine sediments. Analysis of the seismic data yielded computed sediment densities of the bottom and subbottom material which may vary by ± 0.20 g/cm^3 from insitu values. Near-surface material densities are primarily in the 1.4 to 1.8 g/cm^3 range throughout the project area. These computed density values are representative of silty clay to sandy silt and correlate well with CESWG and WES core information.

Below the depth of proposed maintenance dredging (-45 ft MLT), the material becomes a compacted clay which is detected in many of the deeper core logs. This material has computed densities as high as 2.2 g/cm^3. The highest density clays are located in the southern half of the Anchorage Basin at an elevation of -50 ft MLT.

More competent sediments interpreted as sandy material are located in primarily three areas: along the south toe of the Inner Bar Channel, along the north toe of the channel near Station 5+500, and the northwestern corner of the Anchorage Basin. The thicknesses of the interpreted sandy material are not readily known due to the similar density values of the sandy material and underlying stiff clay. Additional cores in these areas are needed to delineate the thickness. The volume of sandy material to be removed through dredging and available for other beneficial use is estimated at 500,000 to 540,000 yd^3 along the south side of the Inner Bar Channel (outbound shipping lane). Of this quantity, approximately 160,000 yd^3 are considered to be poorly graded, clean sands.

Analysis of the seismic information provides a continuous description of the bottom and subbottom sediments in terms of density and material type. The sediment characteristics and profiles highlight changes in the actual subbottom conditions and delineates the extent and depth of various geologic features. This information will be especially helpful in coordinating and completing a sediment coring program or proposed maintenance or new work dredging effort.

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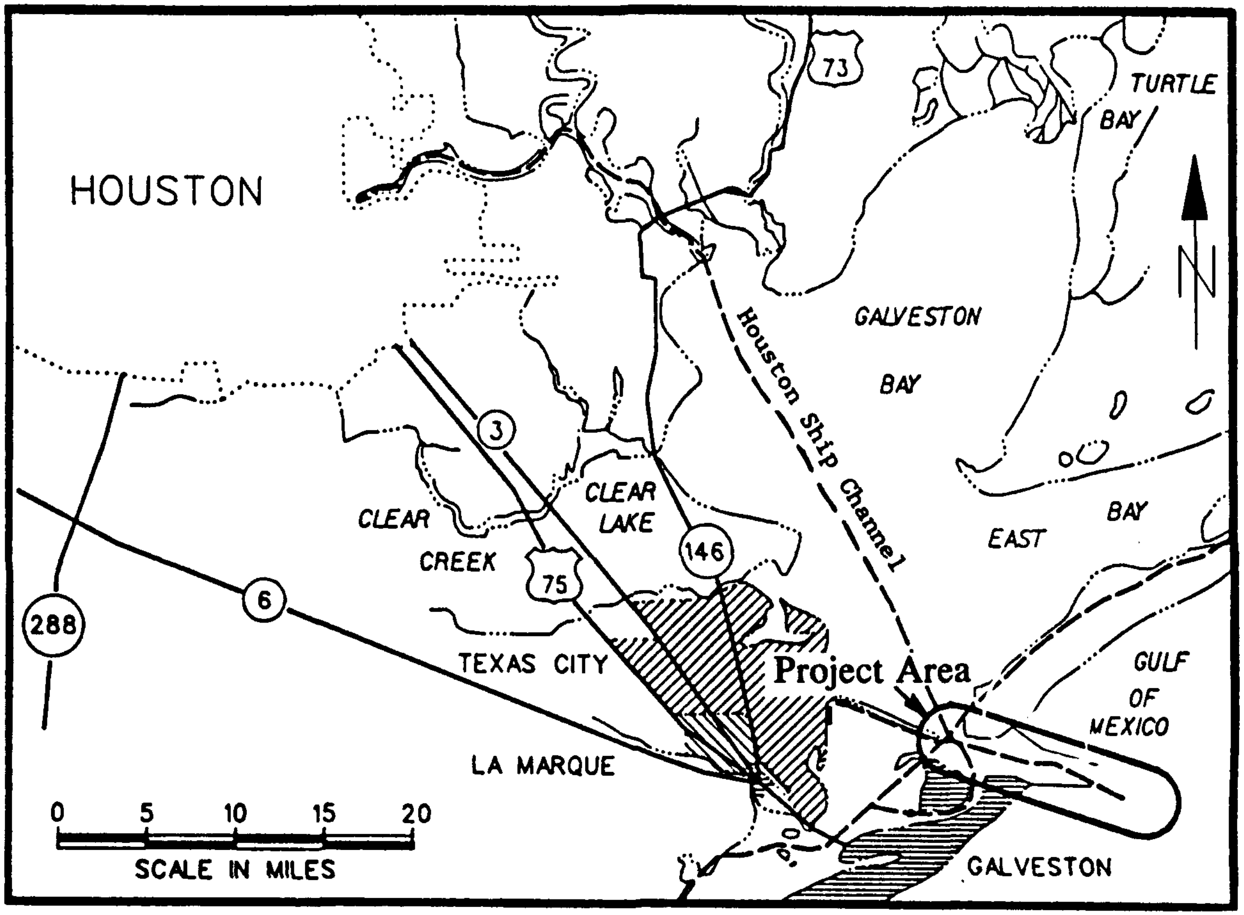

Figure 1. Site map showing location of project area near Galveston, Texas

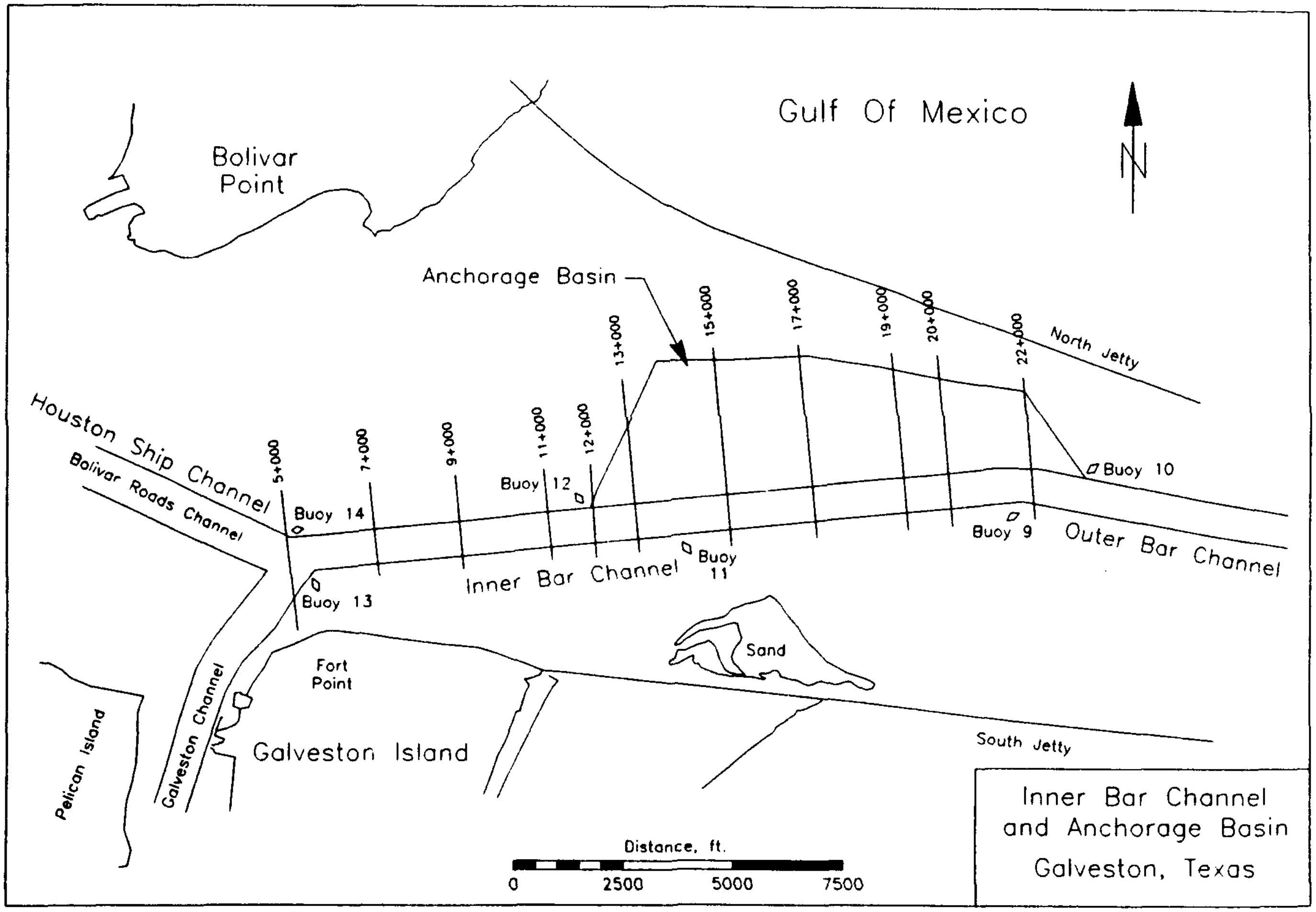

Figure 2. Site map of Inner Bar Channel and Anchorage Basin showing CESWG channel stationing

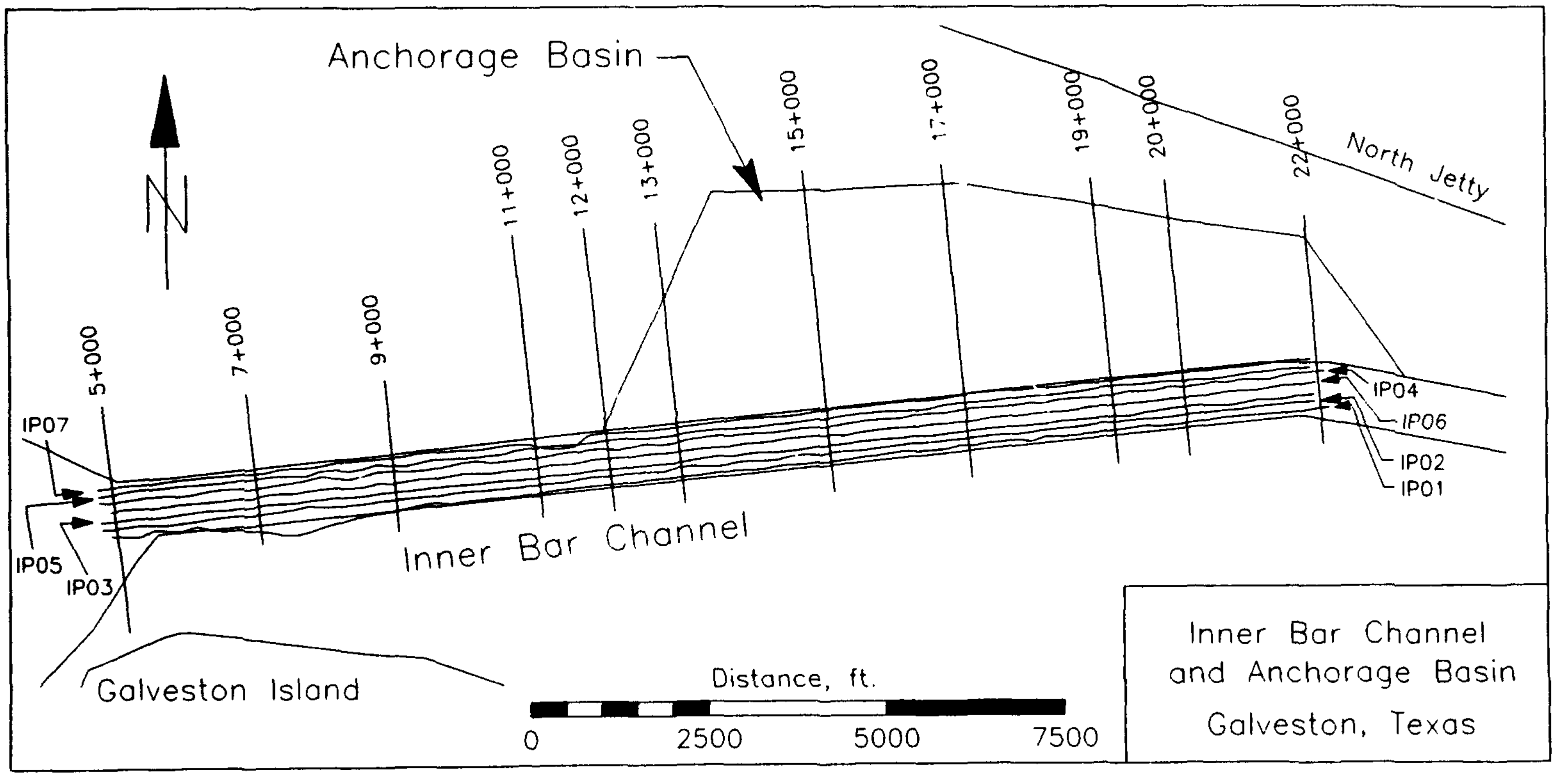

Figure 3. Geophysical survey lines, Inner Bar Channel. Survey direction denoted by label arrow

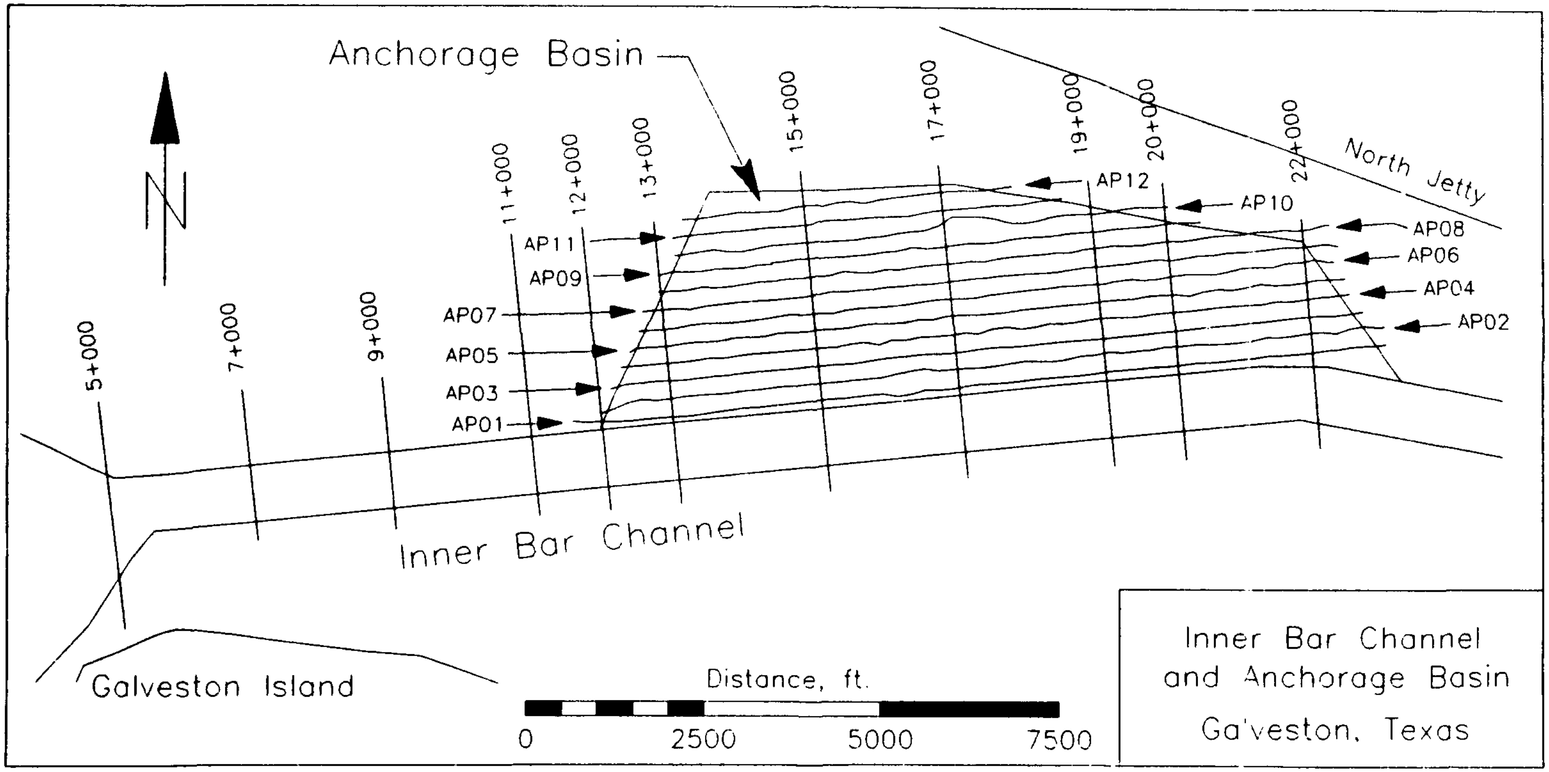

Figure 4. Geophysical survey lines, Anchorage Basin. Survey direction denoted by label arrow

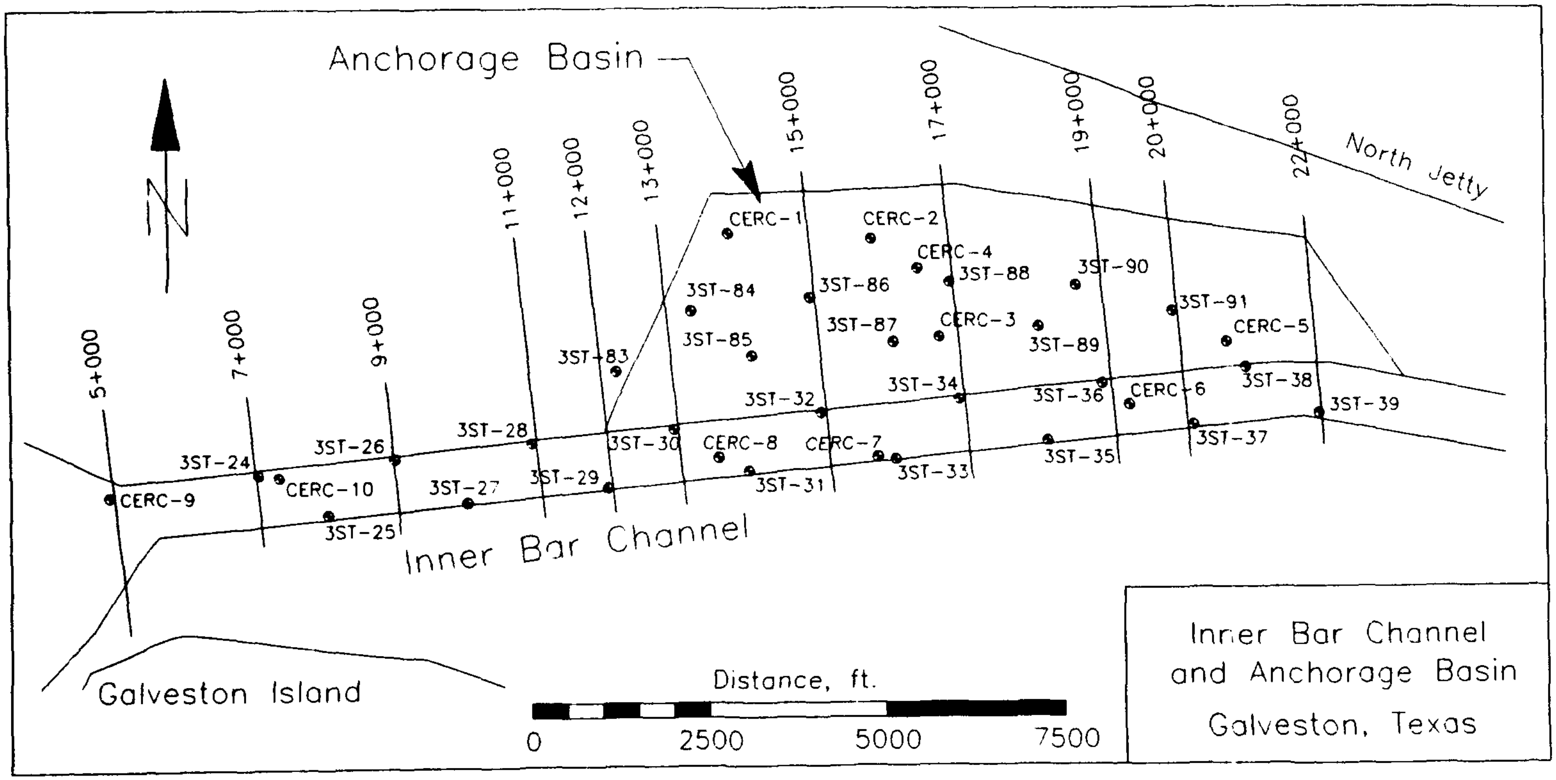

Figure 5. Site map showing CESWG and WES core locations

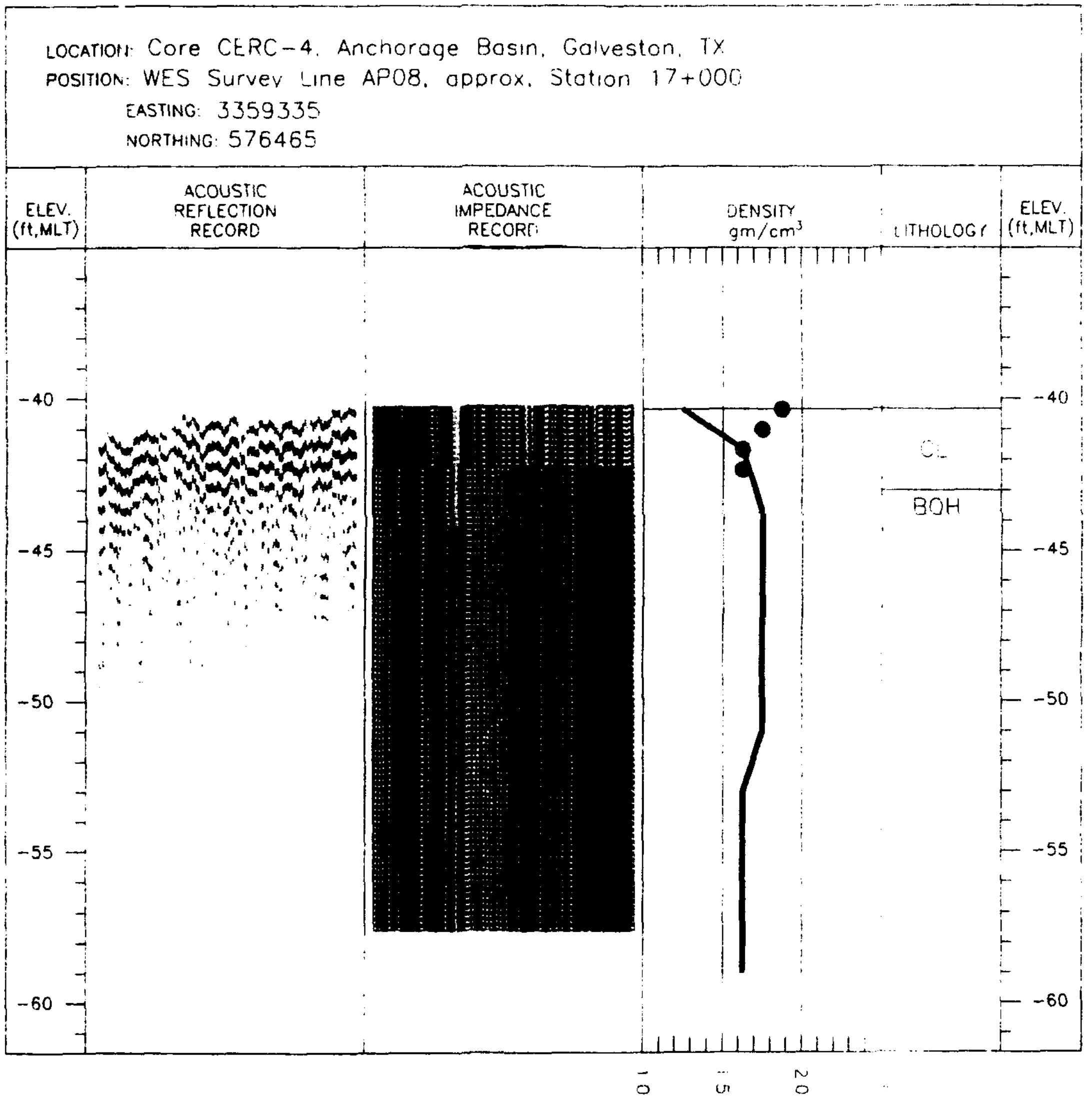

Figure 6. Bottom surface calibration at WES Core CERC-4, Anchorage Basin

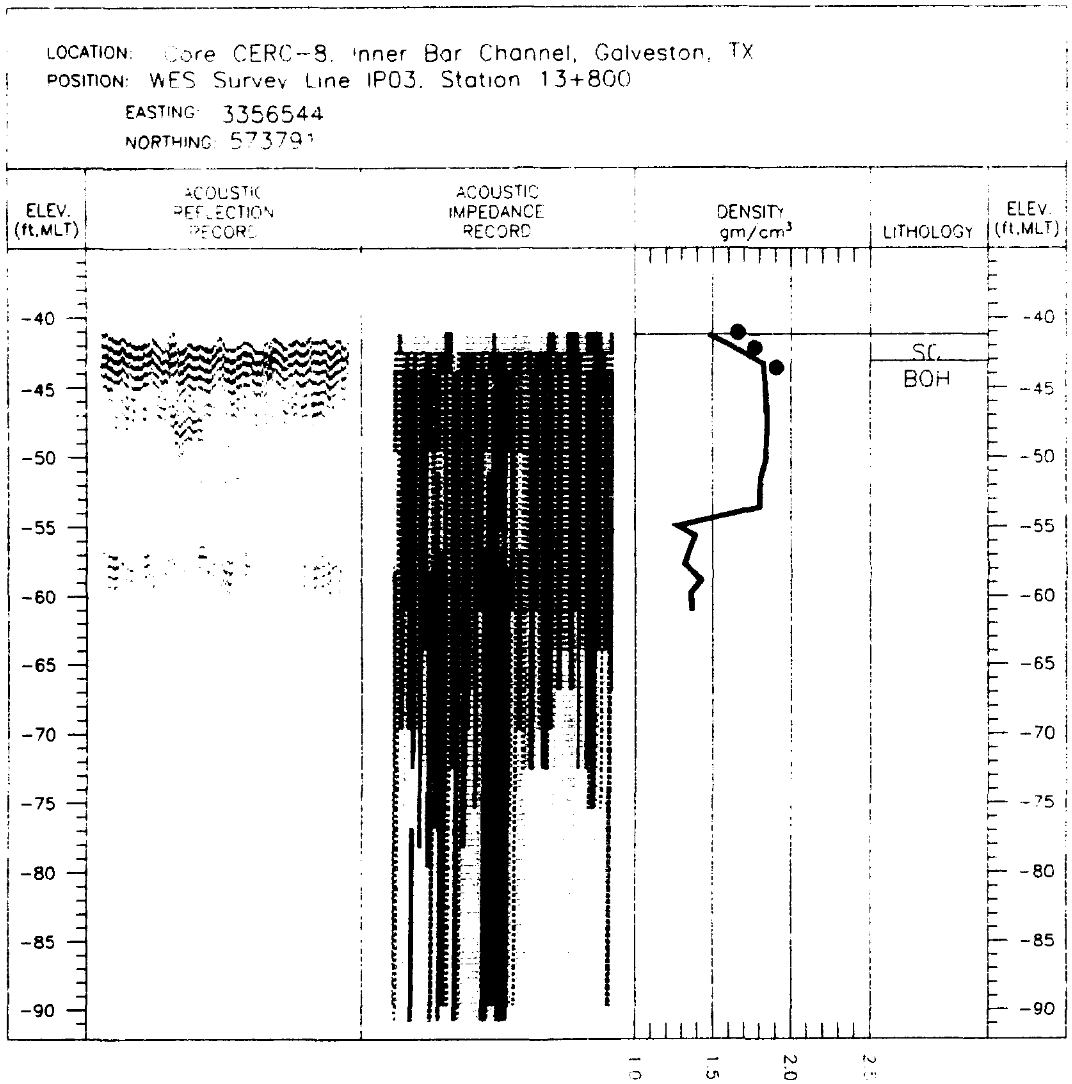

Figure 7. Bottom surface calibration at WES Core CERC-8, Inner Bar Channel

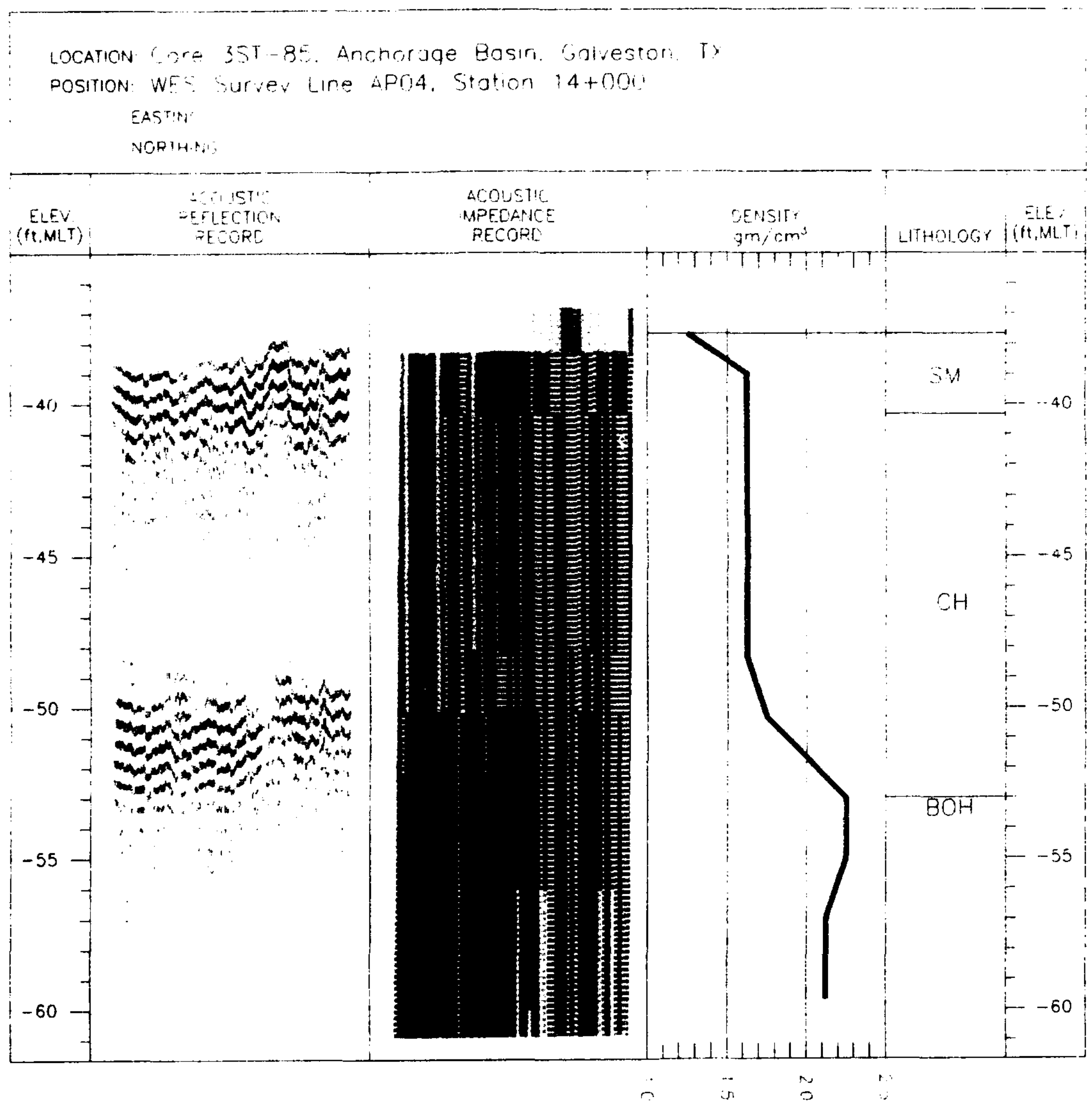

Figure 8. Subbottom sediment calibration at Core 3ST-85, Anchorage Basin

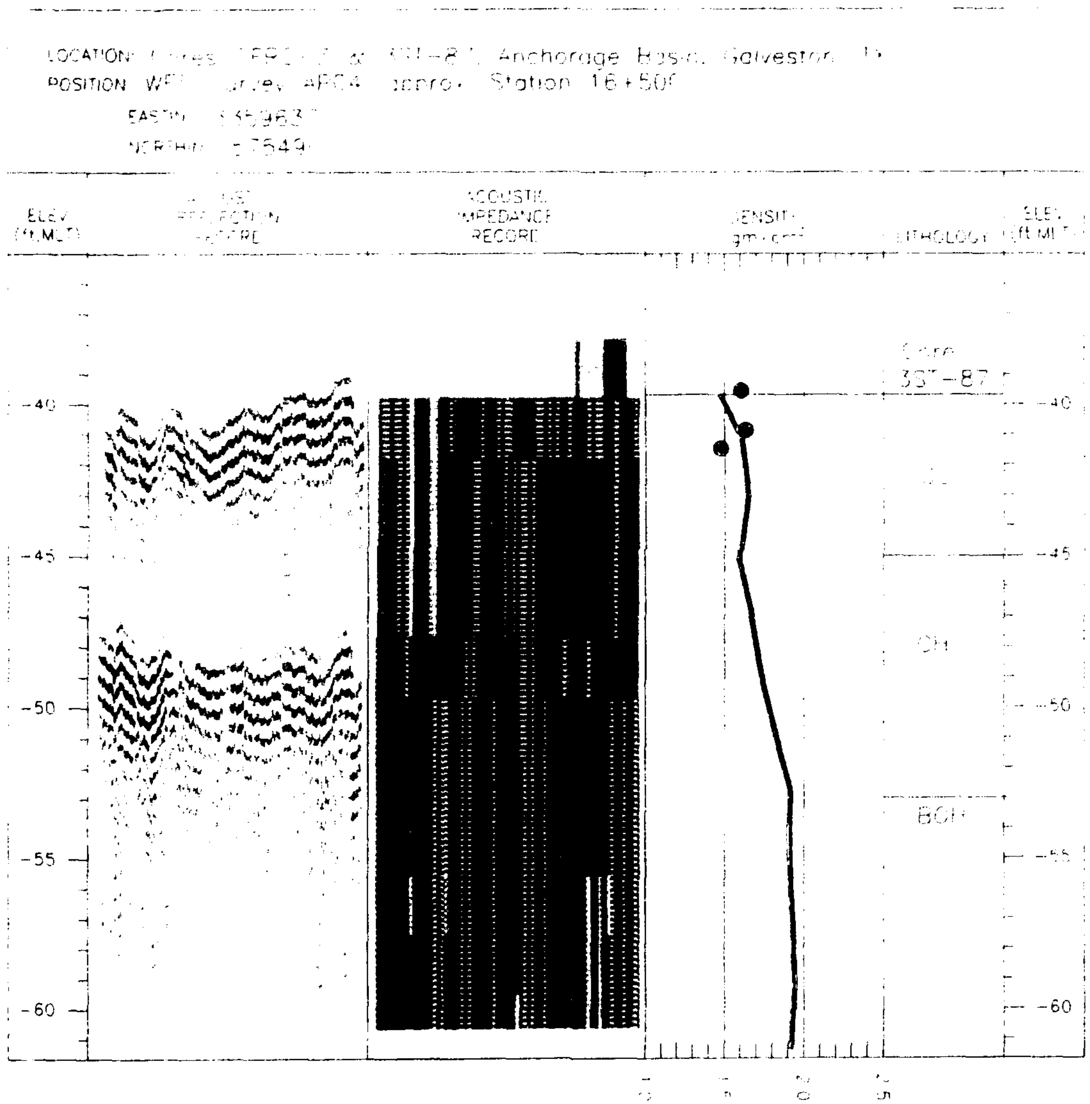

Figure 9. Subbottom sediment calibration at Cores CERC-3 and 3ST-87, Anchorage Basin

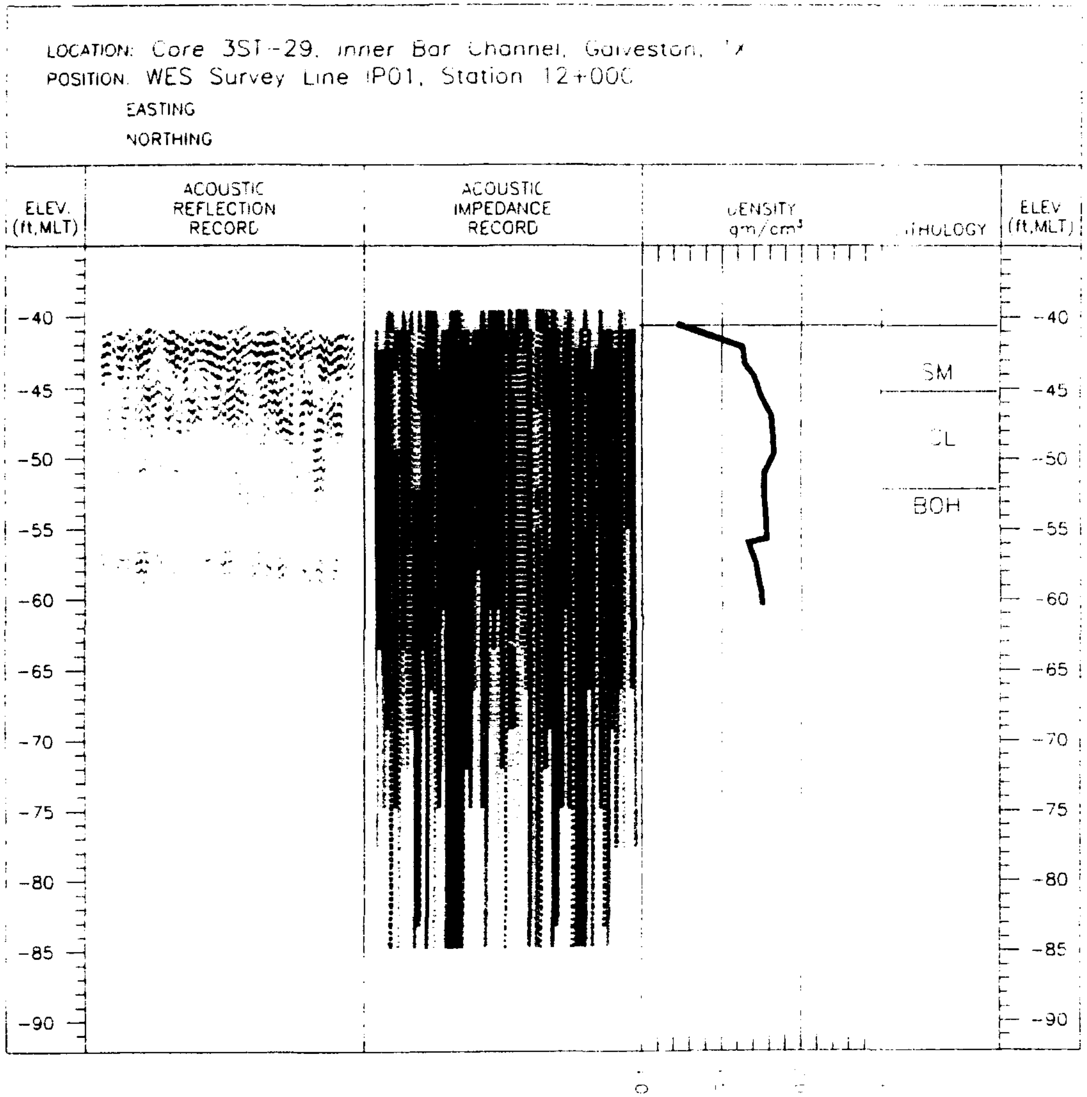

Figure 10. Check calibration at Core 3ST-29, Inner Bar Channel

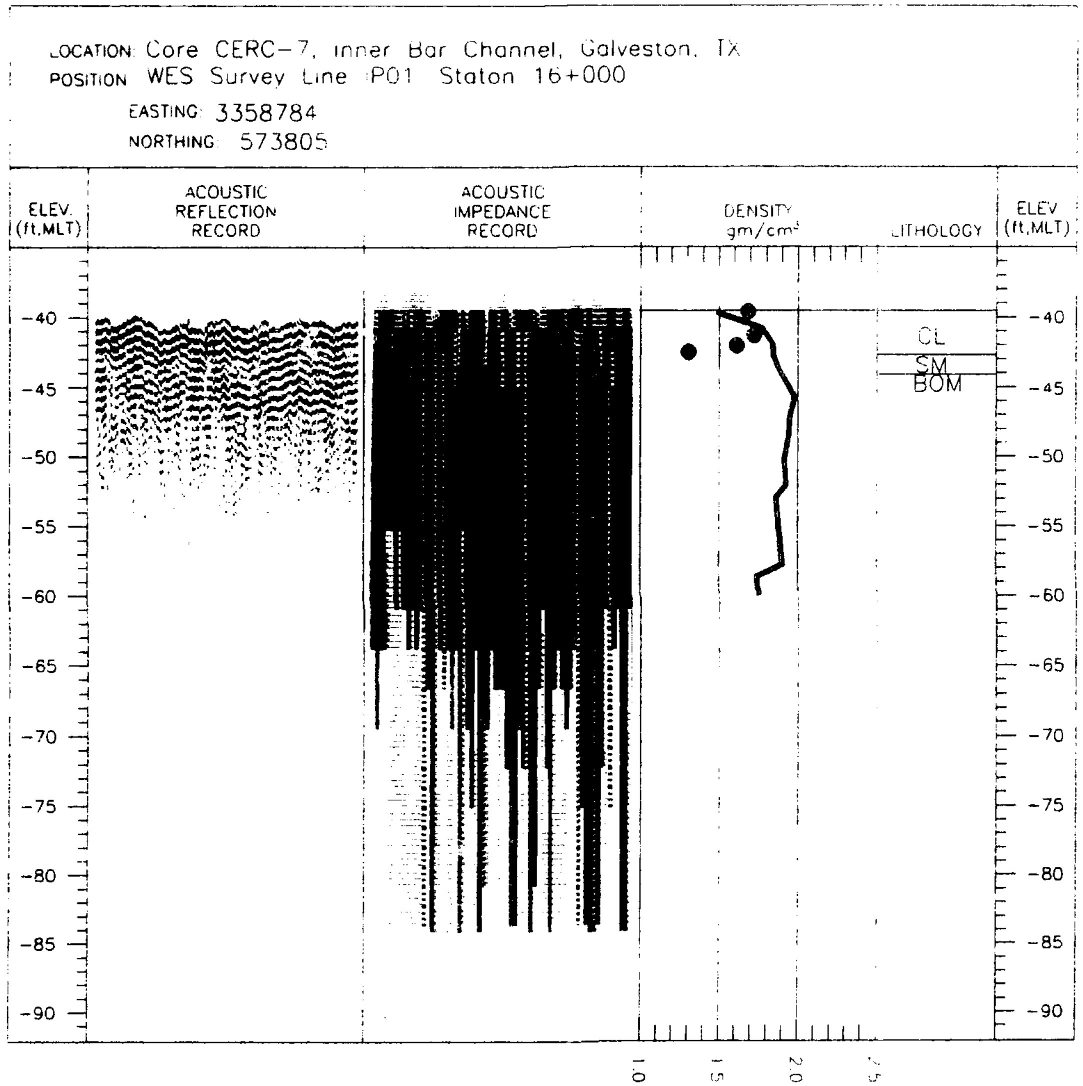

Figure 11. Check calibration at Core CERC-7, Inner Bar Channel

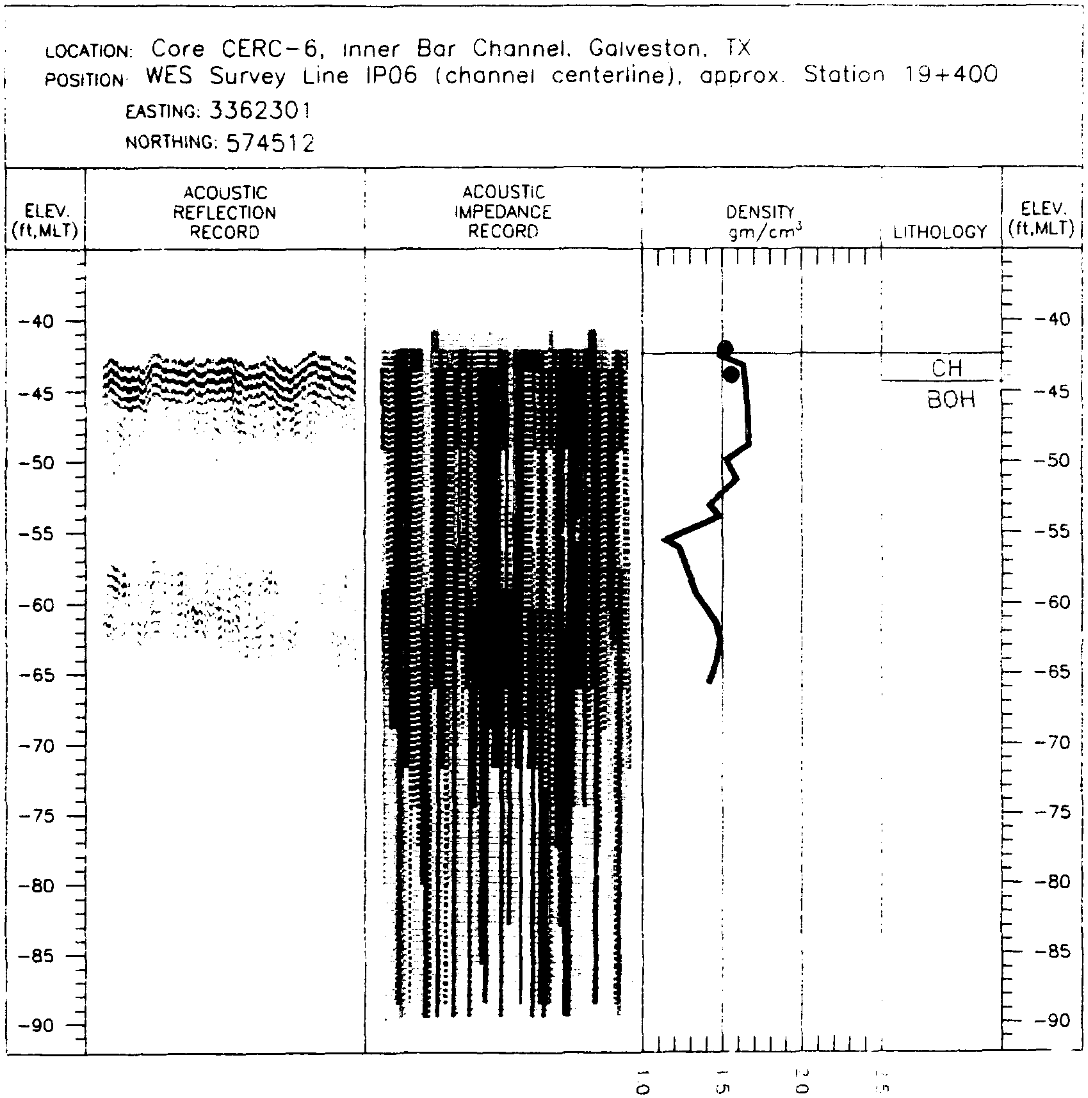

Figure 12. Check calibration at Core CERC-6, Inner Bar Channel

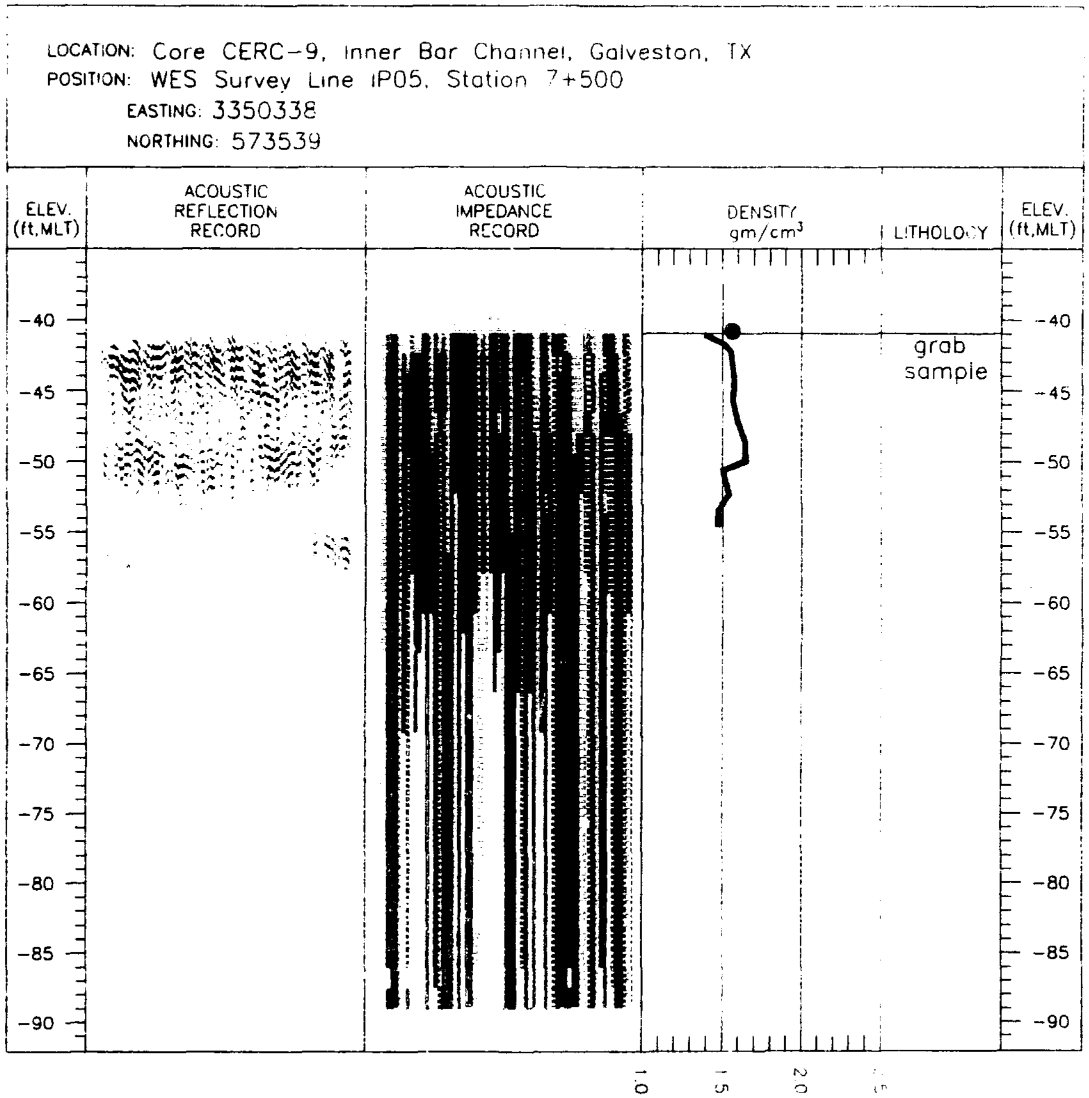

Figure 13. Check calibration at Core CERC-9, Inner Bar Channel

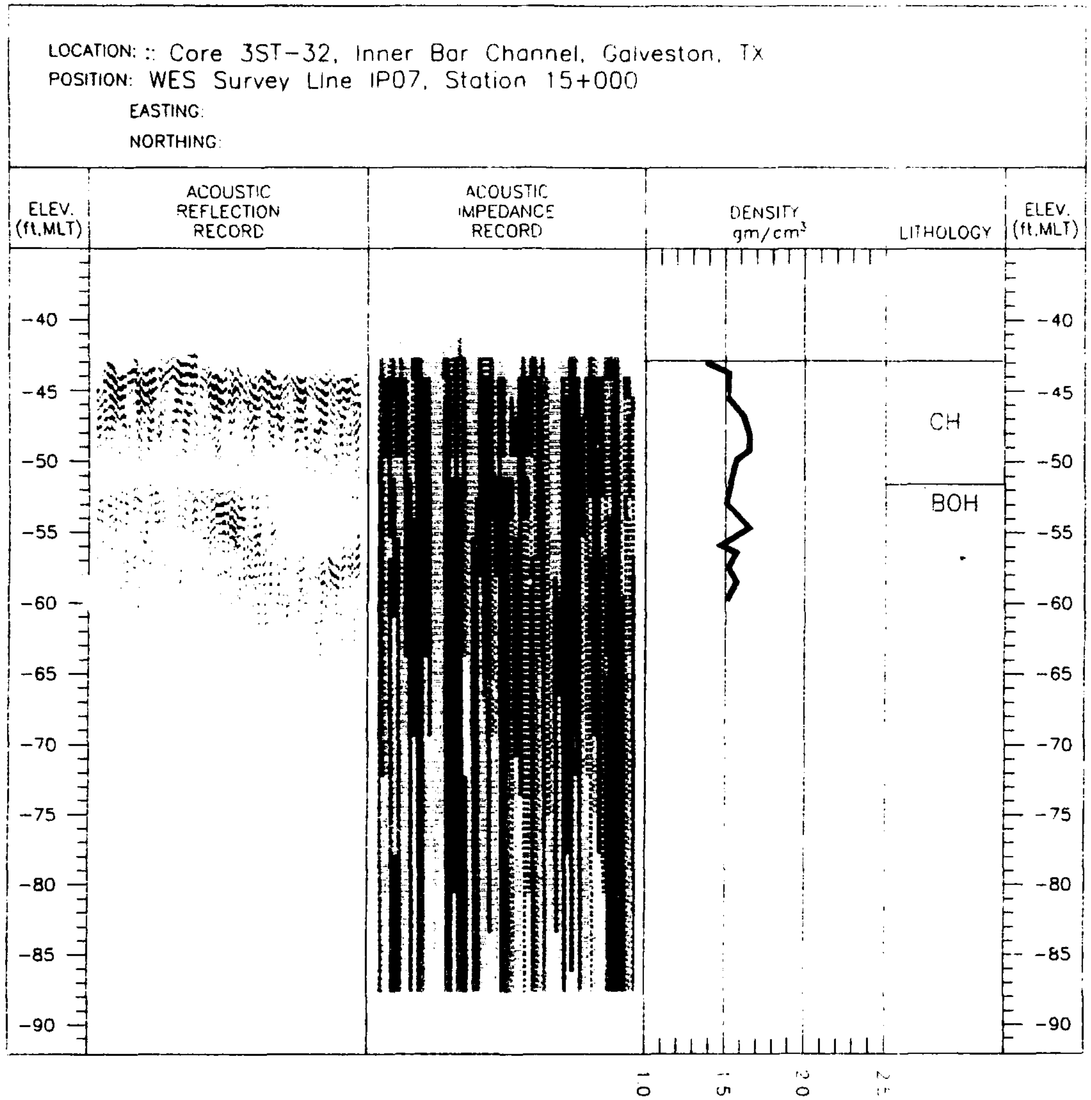

Figure 14. Check calibration at Core 3ST-32, Inner Bar Channel

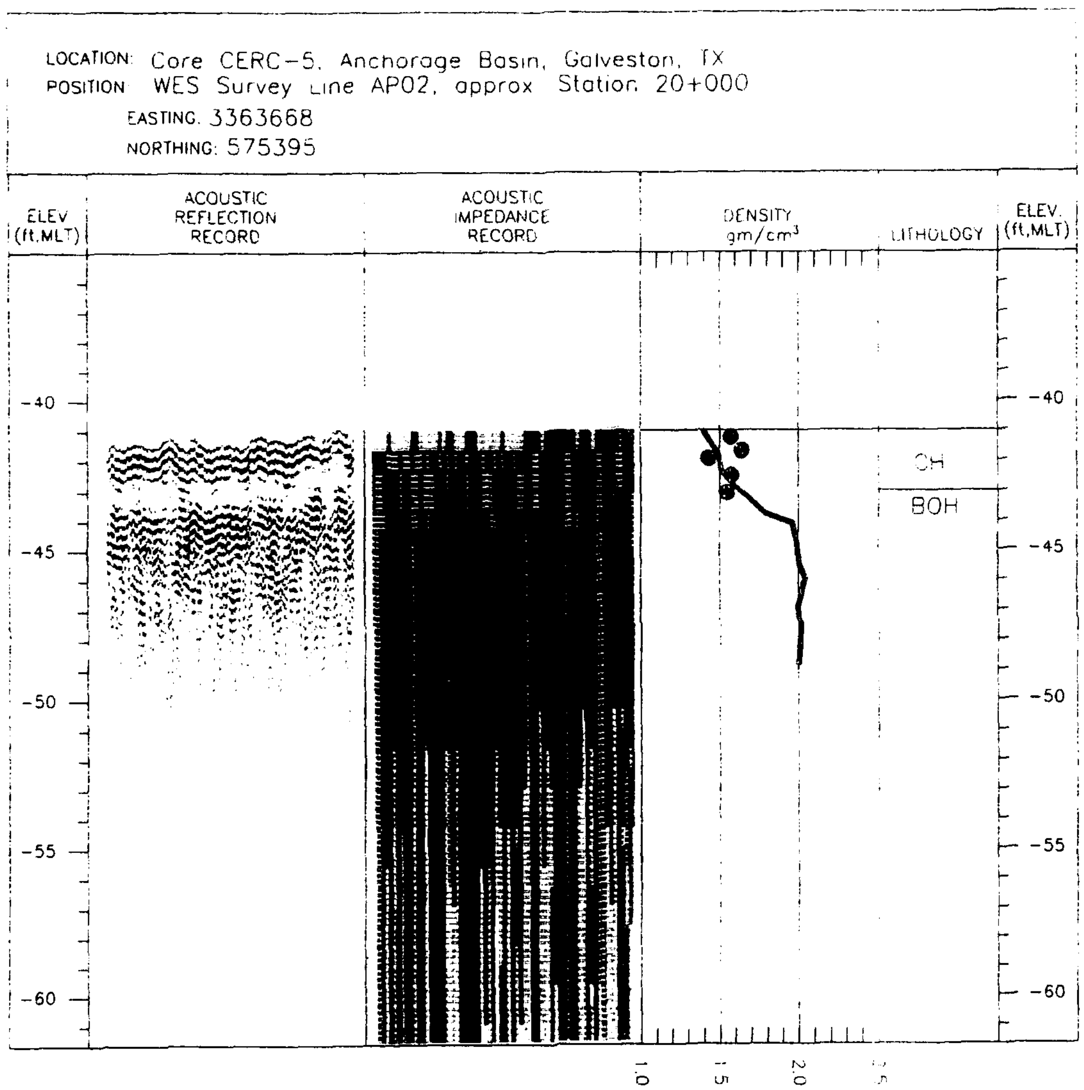

Figure 15. Check calibration at Core CERC-5, Anchorage Basin

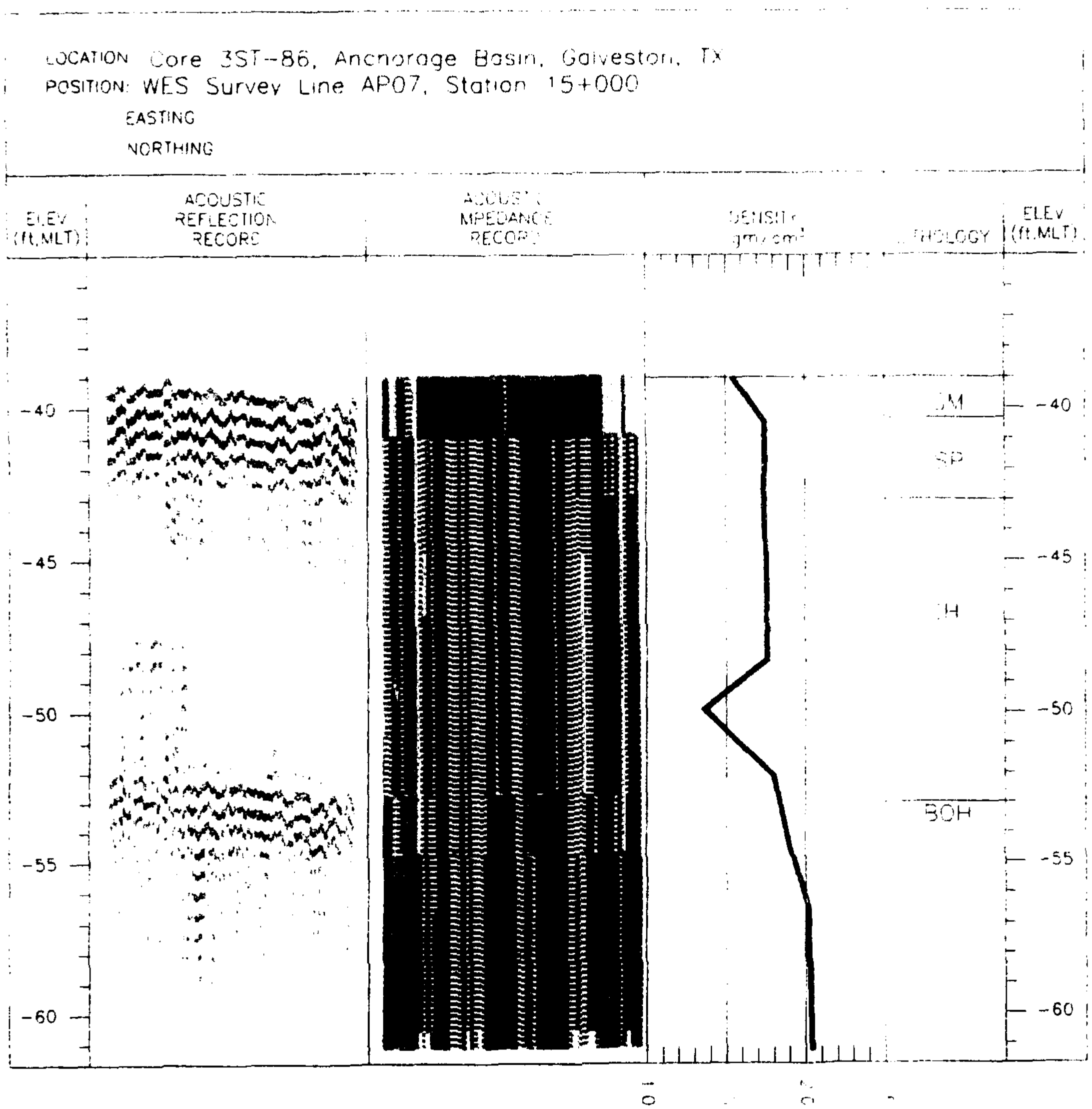

Figure 16. Check calibration at Core 3ST-86, Anchorage Basin

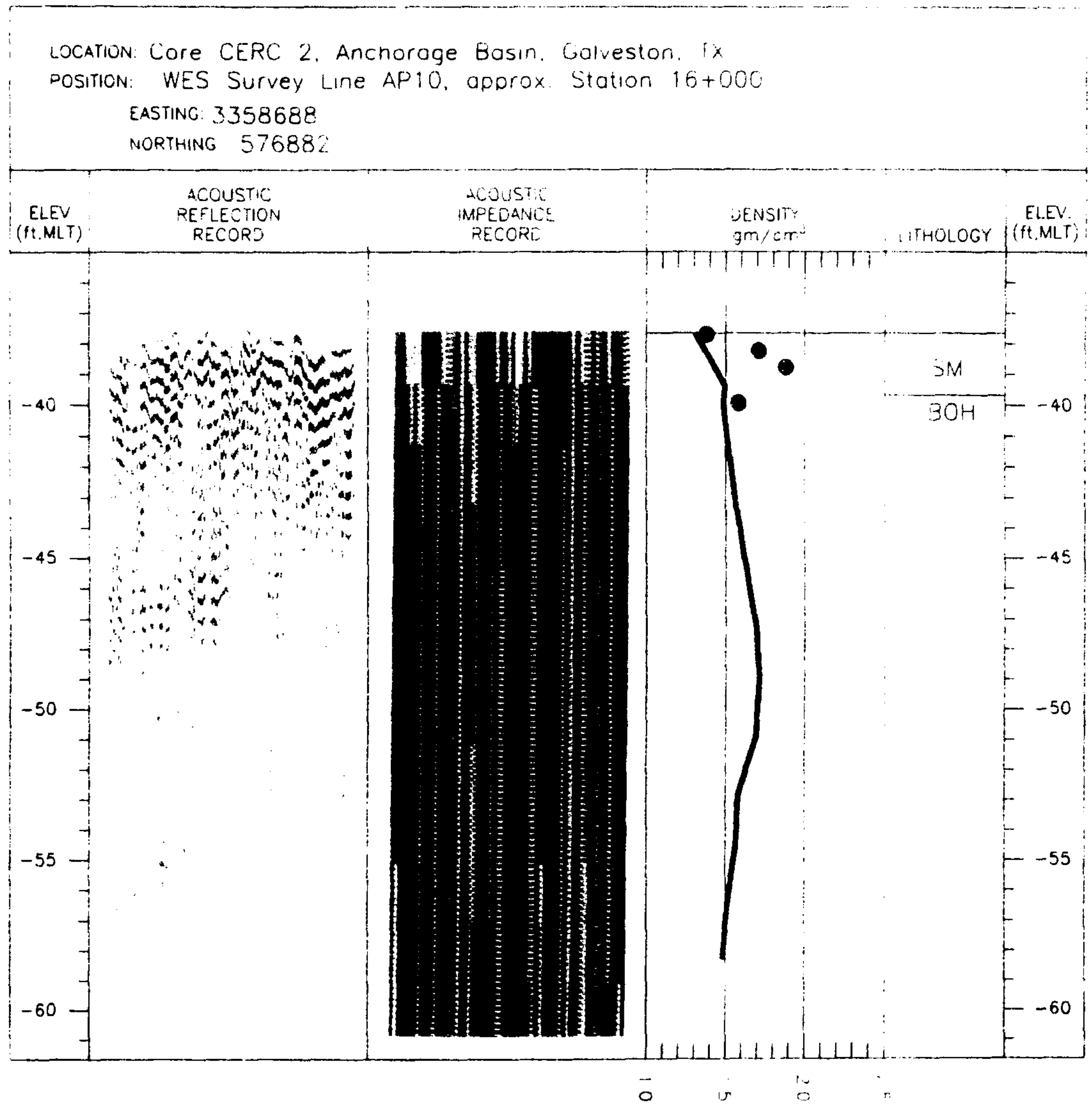

Figure 17. Check calibration at Core CERC-2, Anchorage Basin

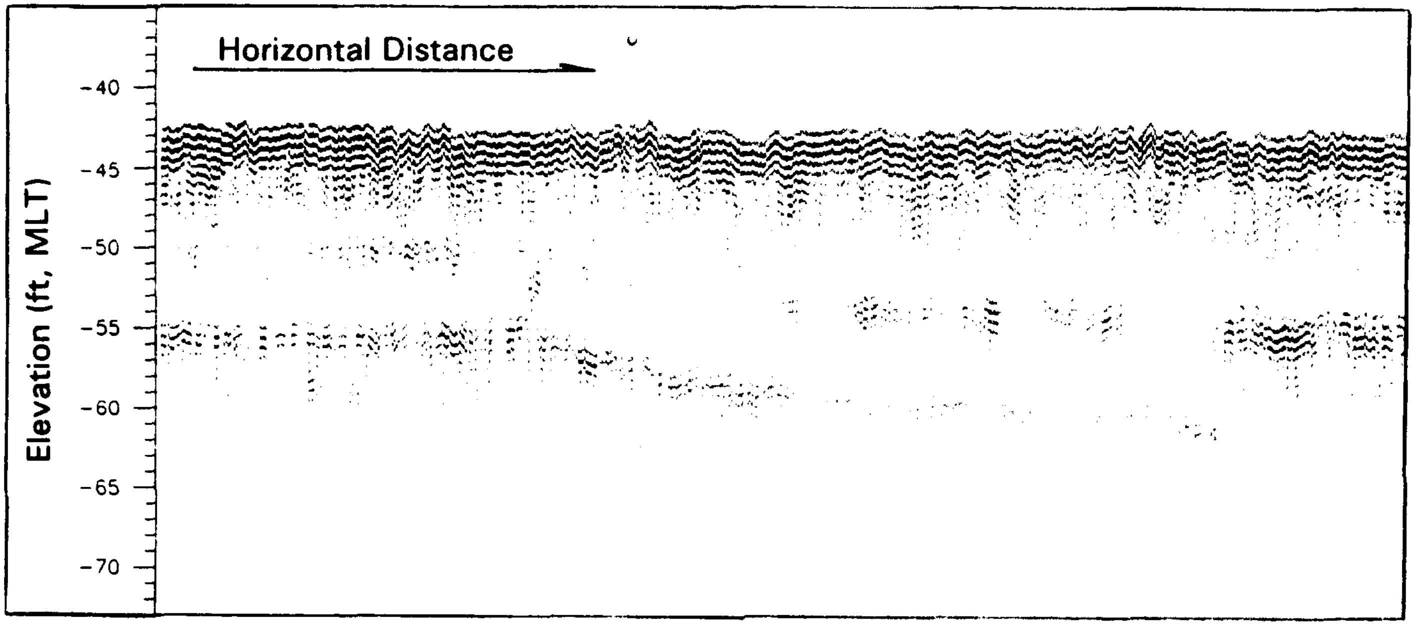

Figure 18. Subbottom reflection record along Survey Line IP06 (files 130 - 153) near Station 12+000, Inner Bar Channel

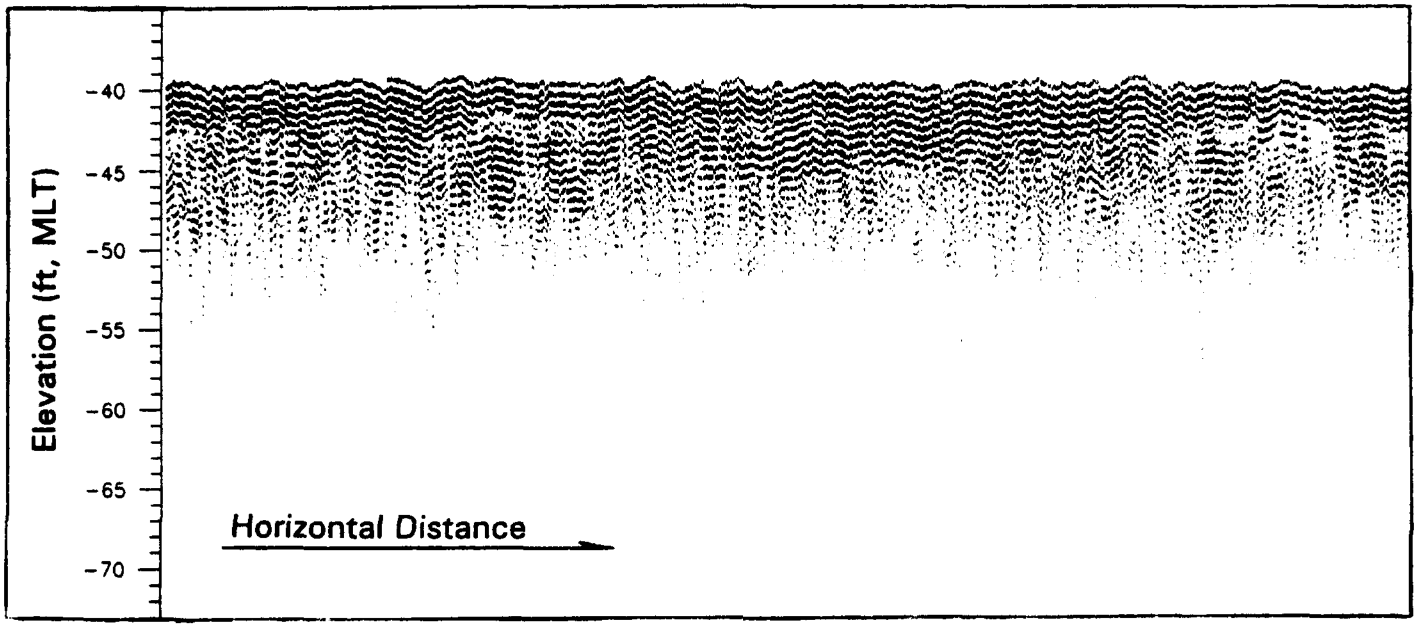

Figure 19. Subbottom reflection record along Survey Line IP01 (files 070 - 093) near Station 16+500, Inner Bar Channel

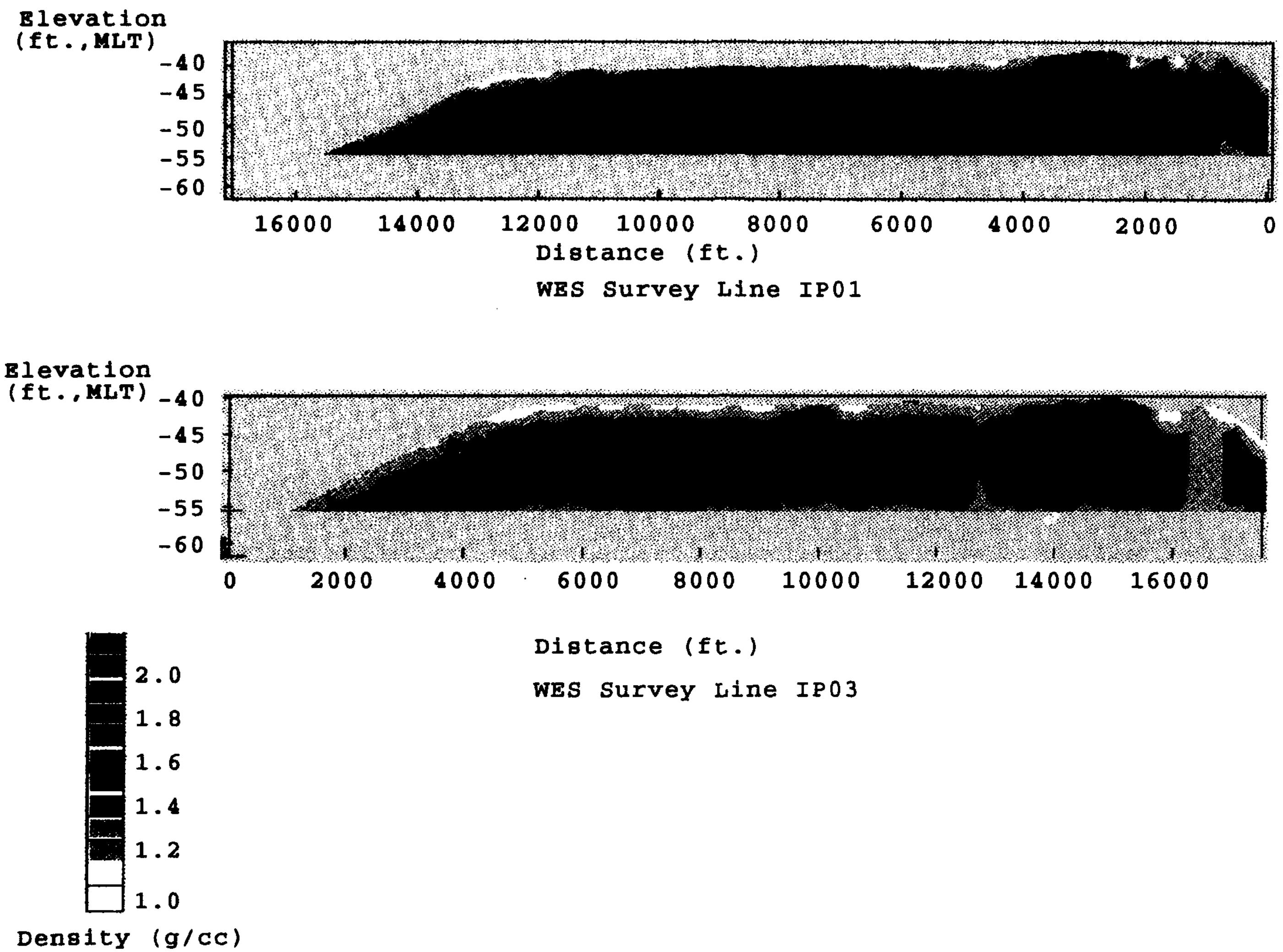

Figure 20. Color-coded density profile along Survey Lines IP01 and IP03, Inner Bar Channel

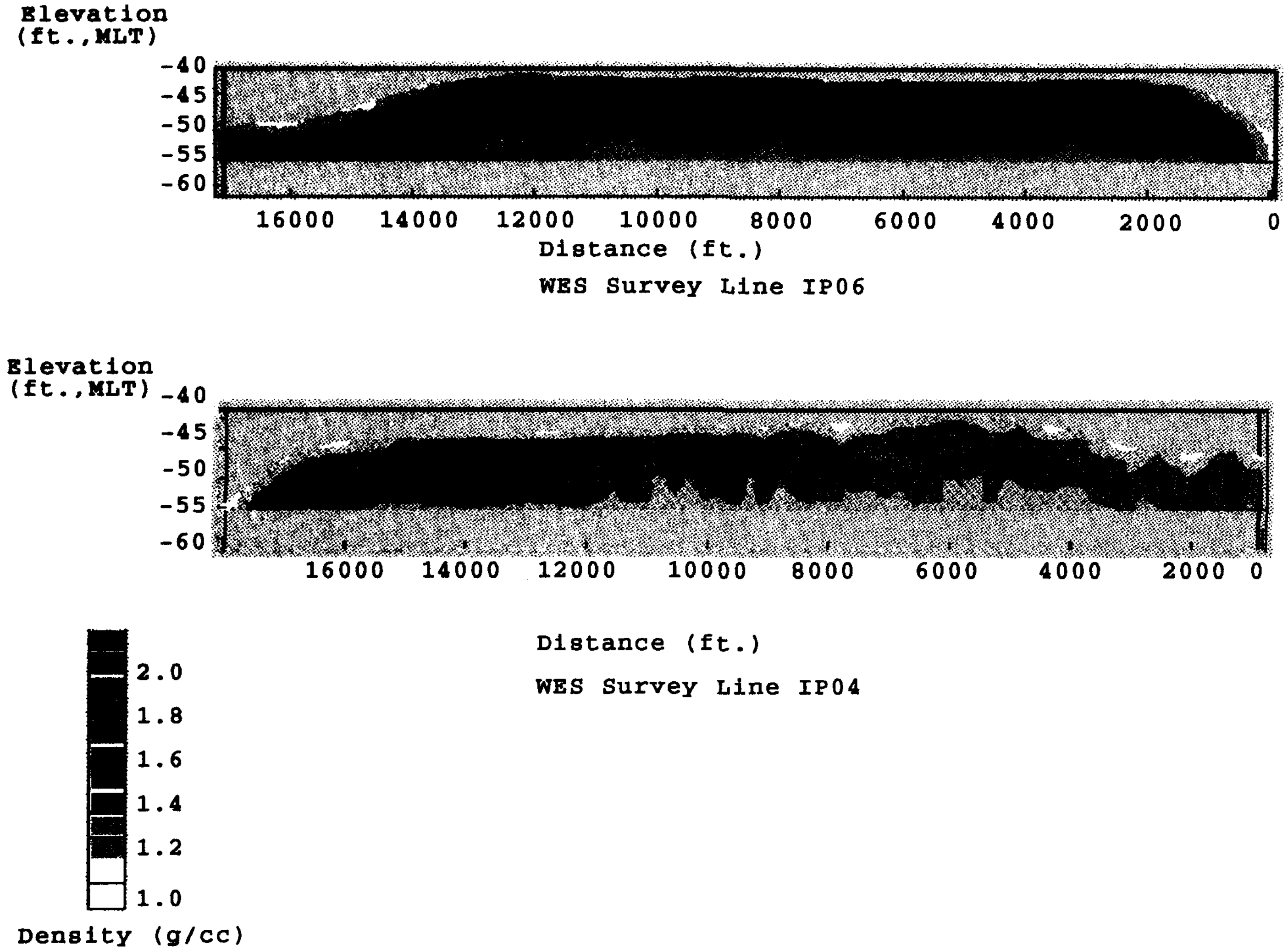

Figure 21. Color-coded density profile along Survey Lines IP06 and IP04, Inner Bar Channel

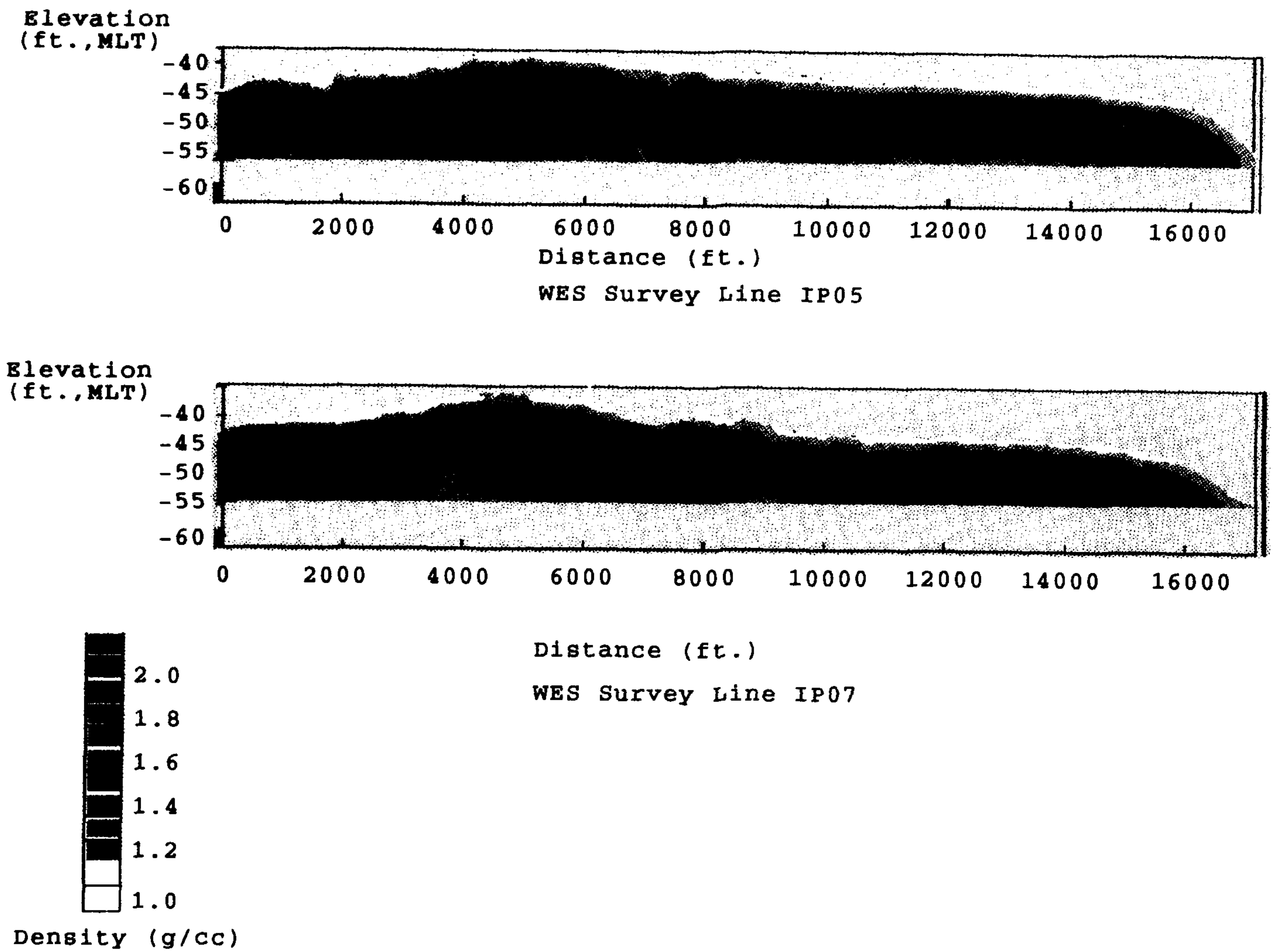

Figure 22. Color-coded density profile along Survey Lines IP05 and IP07, Inner Bar Channel

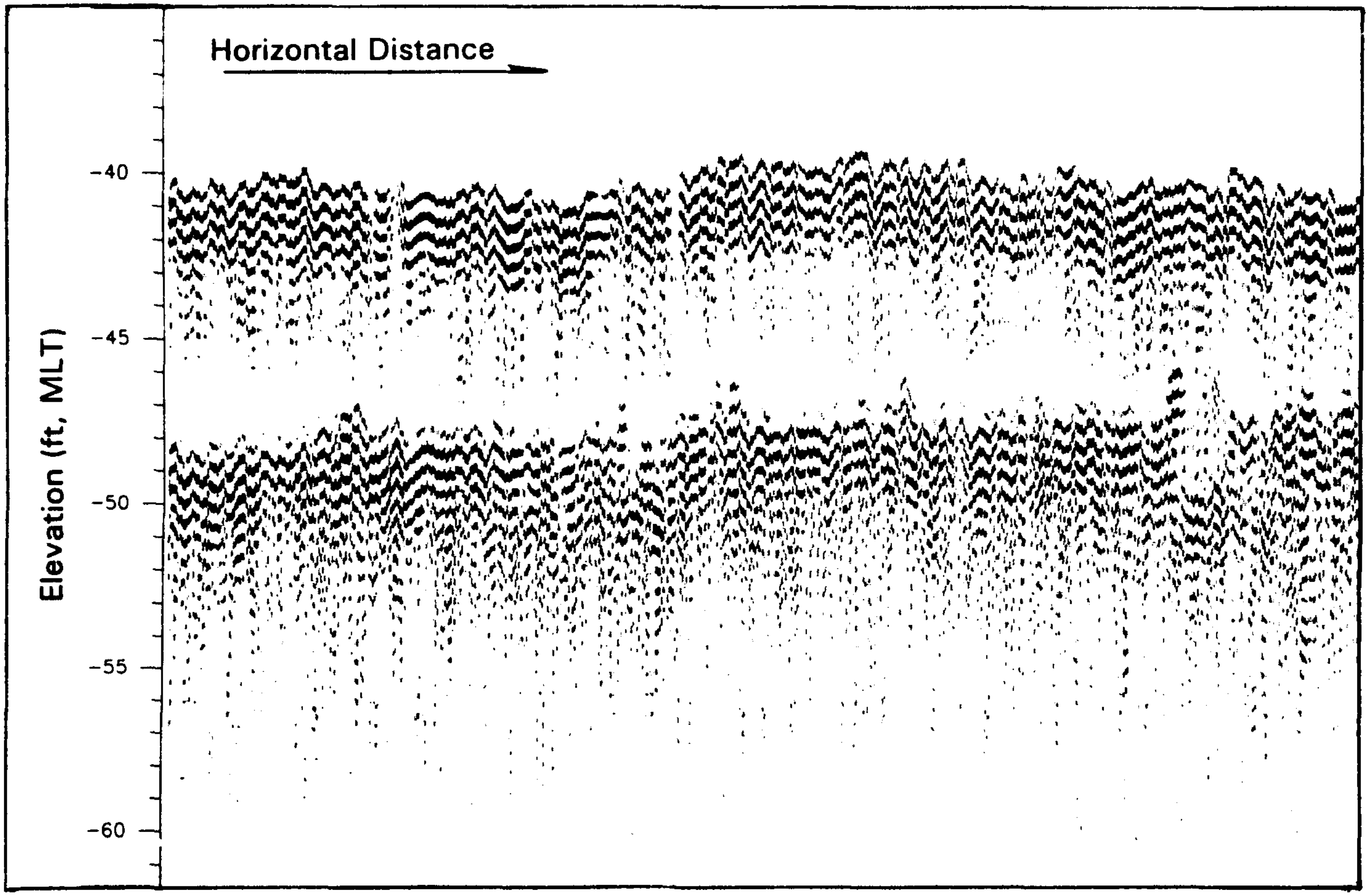

Figure 23. Subbottom reflection record along Survey Line AP05 (files 080 - 103) near Station 16+500, Anchorage Basin

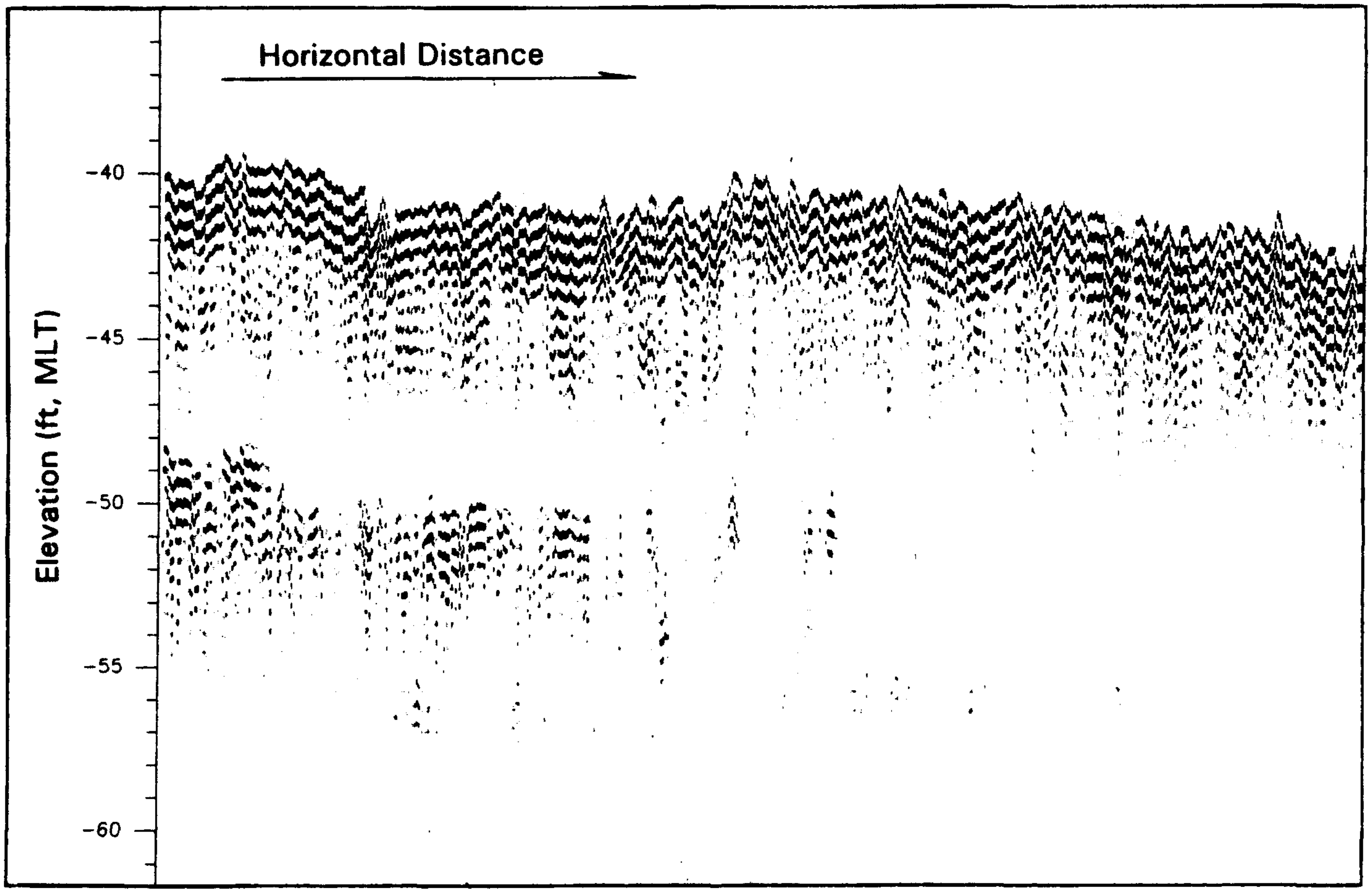

Figure 24. Subbottom reflection record along Survey Line AP07 (files 090 - 113) near Station 17+000, Anchorage Basin

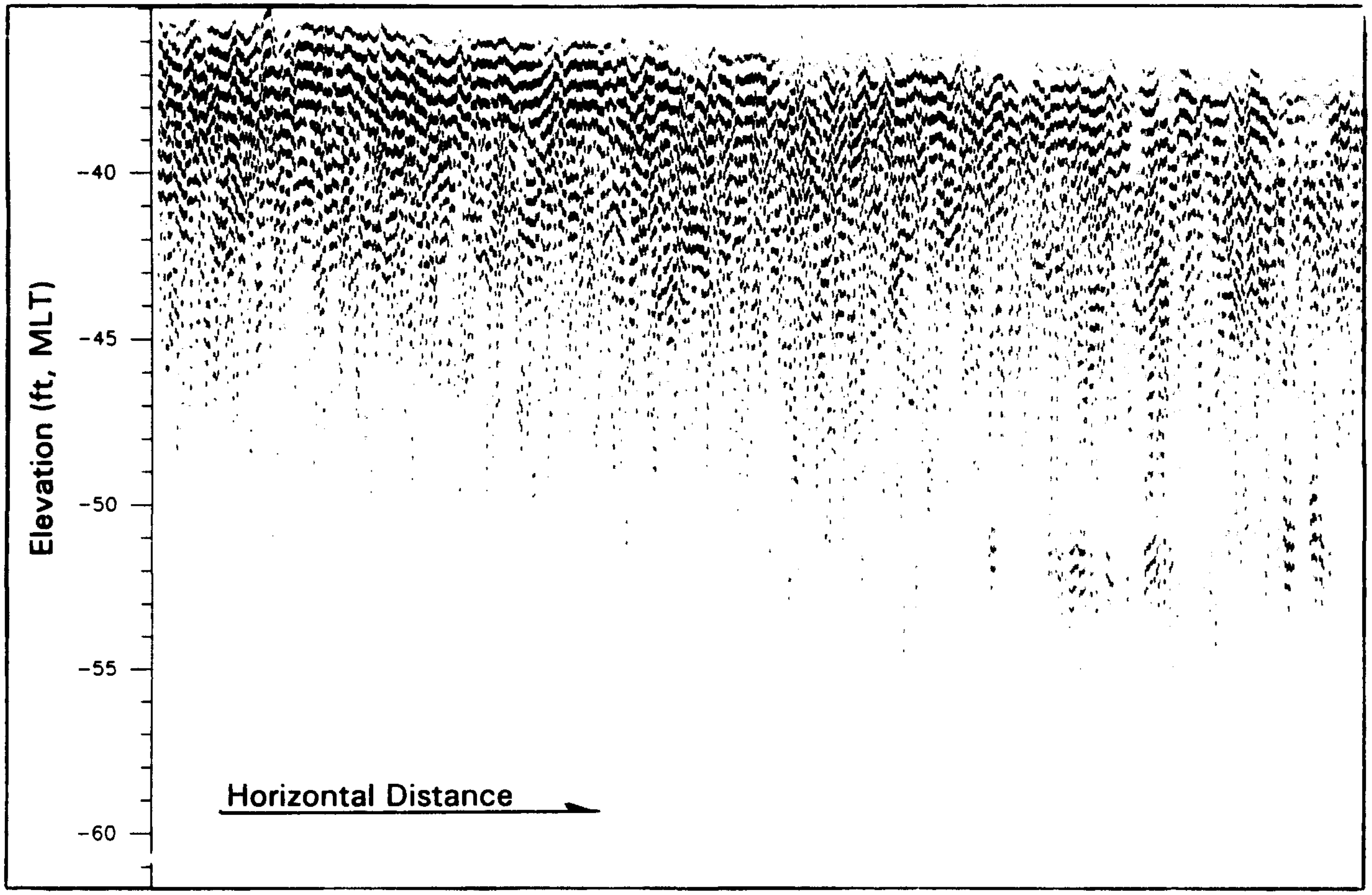

Figure 25. Subbottom reflection record along Survey Line AP11 (files 010 - 033) near Station 14+000, Anchorage Basin

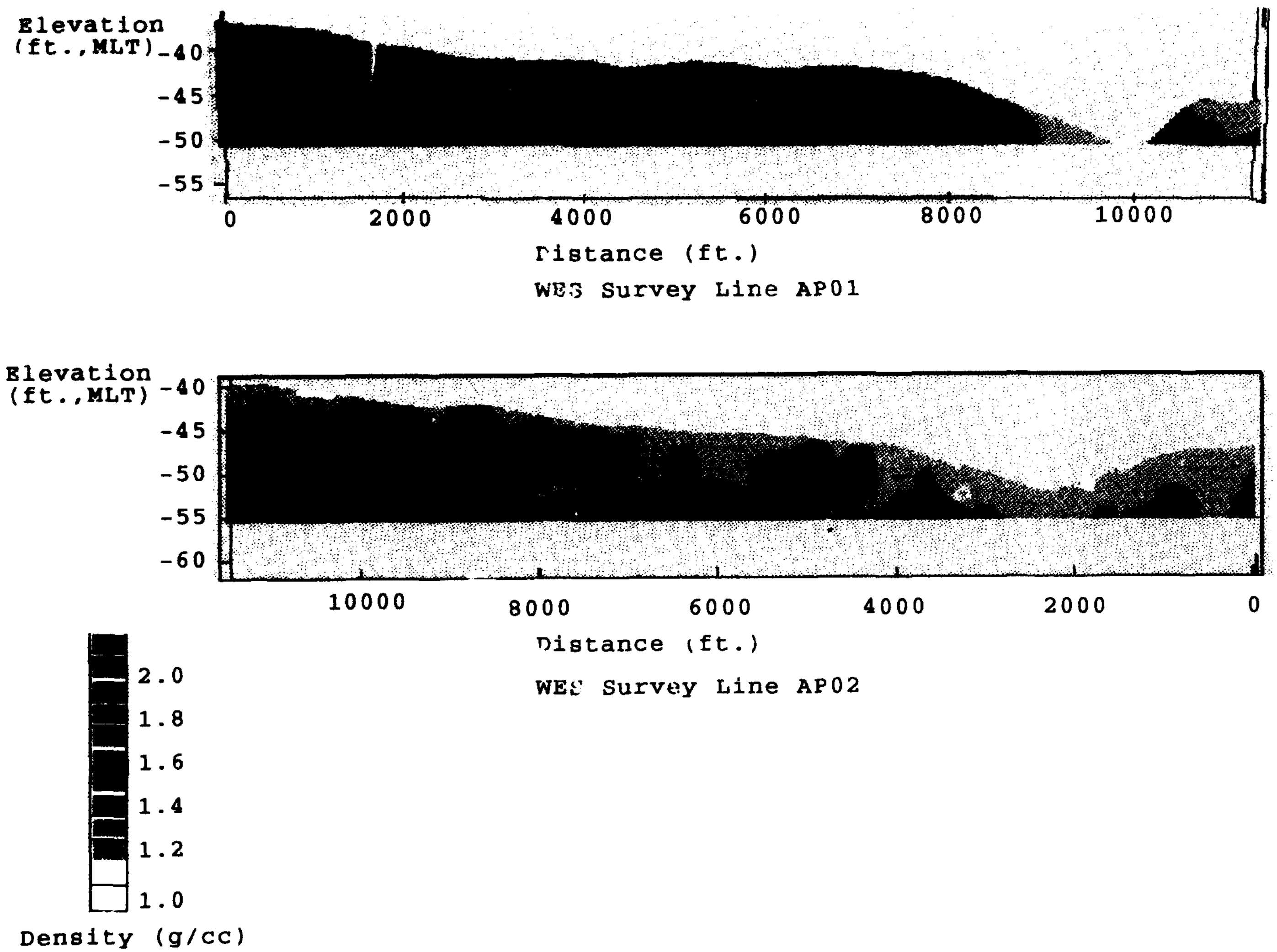

Figure 26. Color-coded density profile along Survey Lines AP01 and AP02, Anchorage Basin

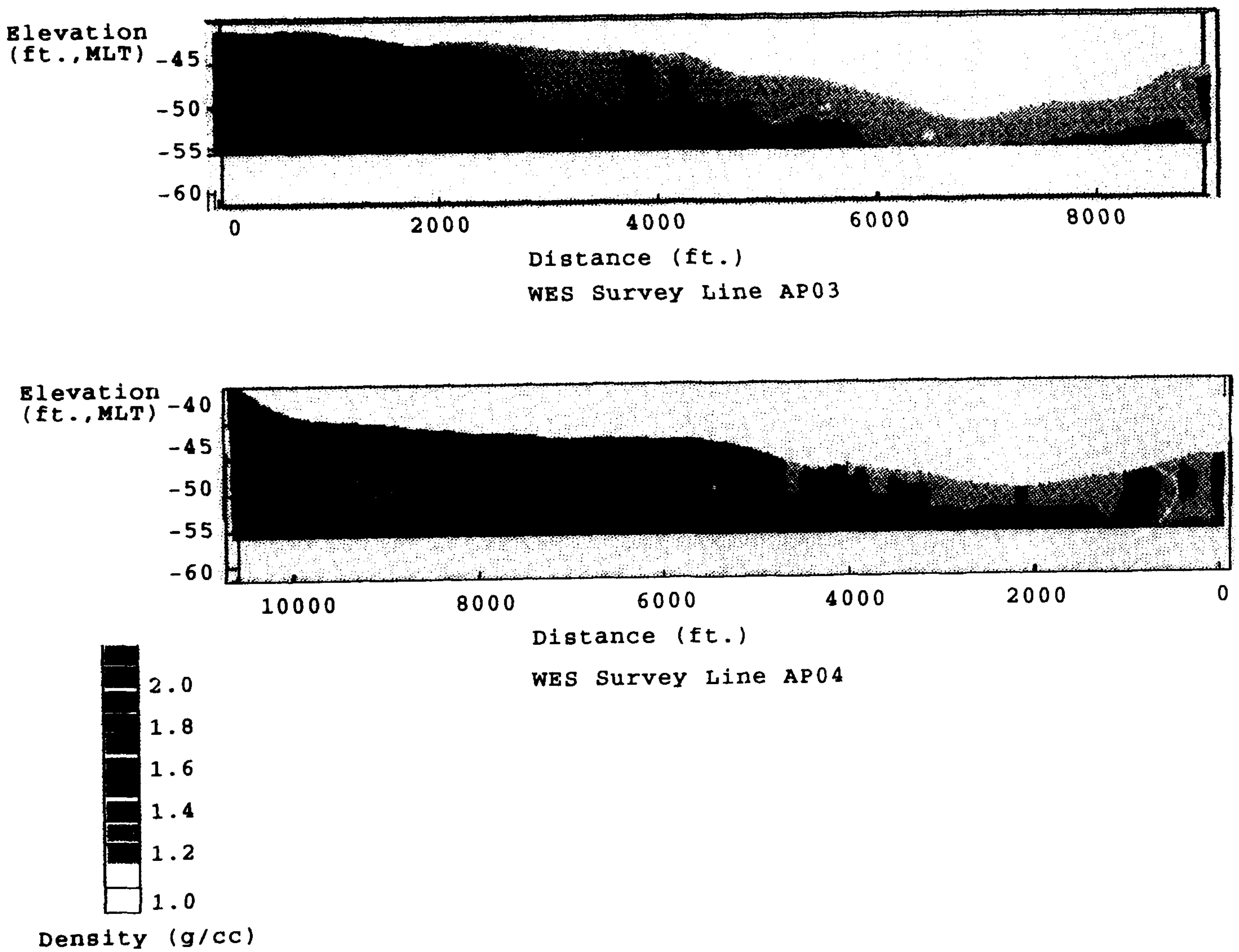

Figure 27. Color-coded density profile along Survey Lines AP03 and AP04, Anchorage Basin

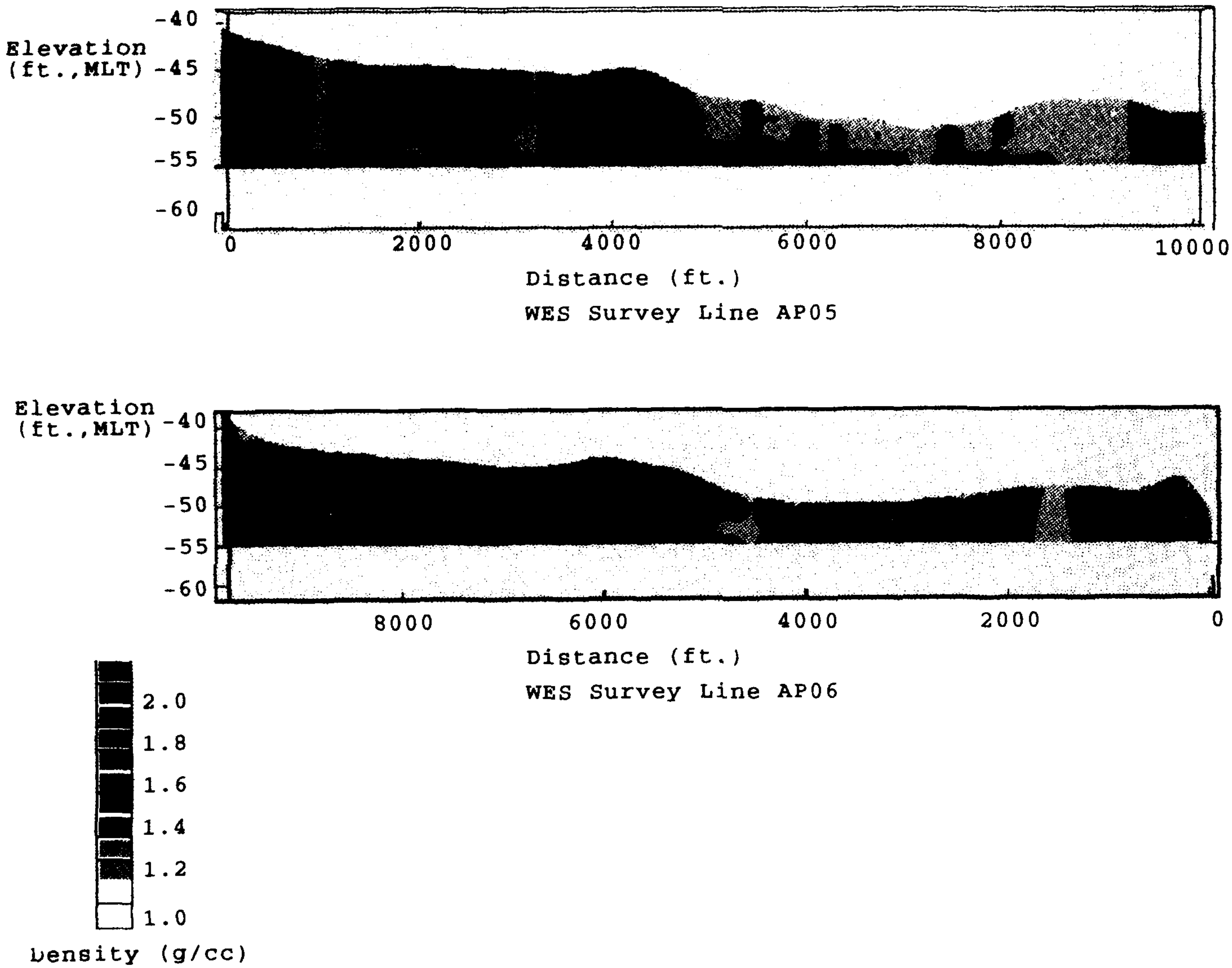

Figure 28. Color-coded density profile along Survey Lines AP05 and AP06, Anchorage Basin

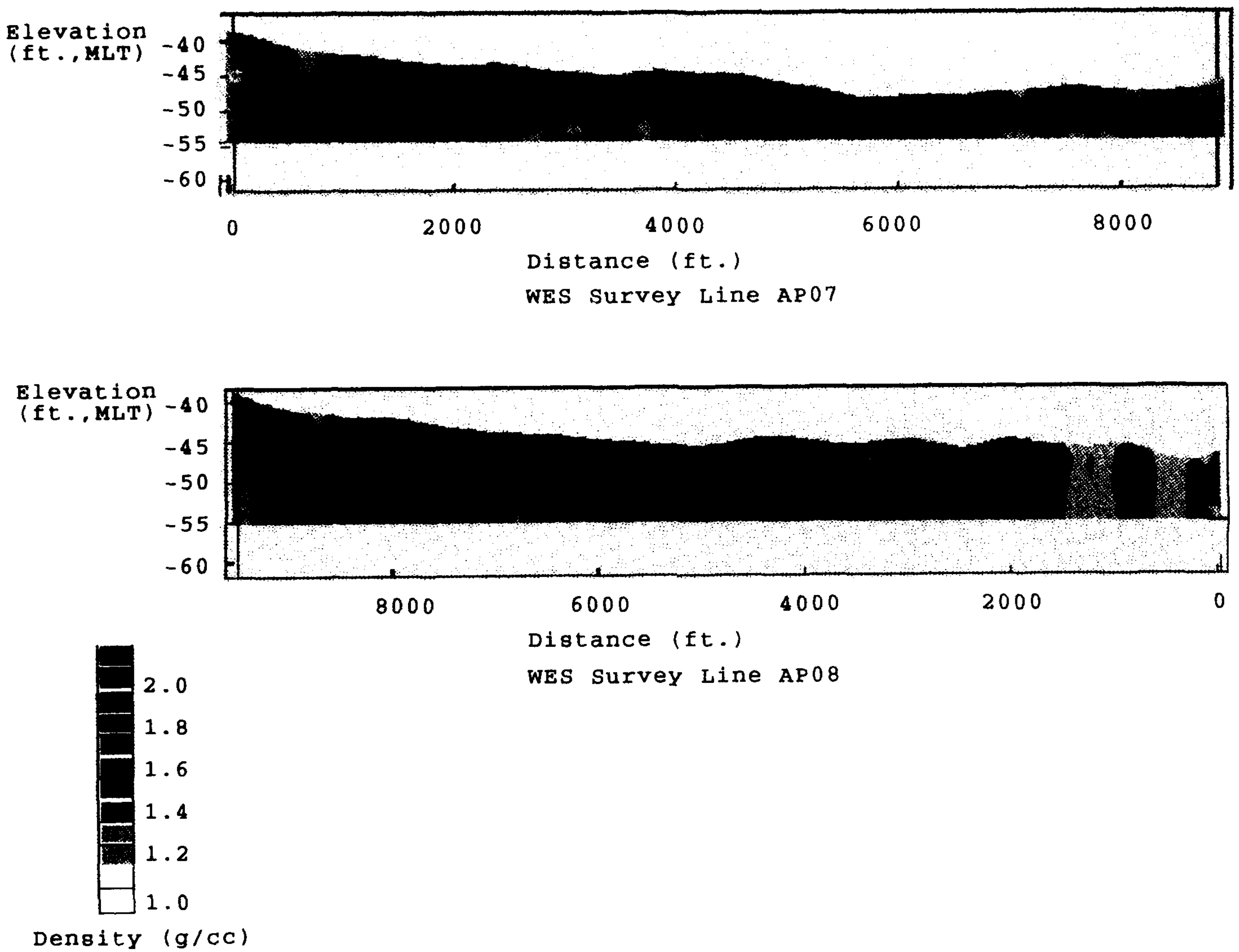

Figure 29. Color-coded density profile along Survey Lines AP07 and AP08, Anchorage Basin

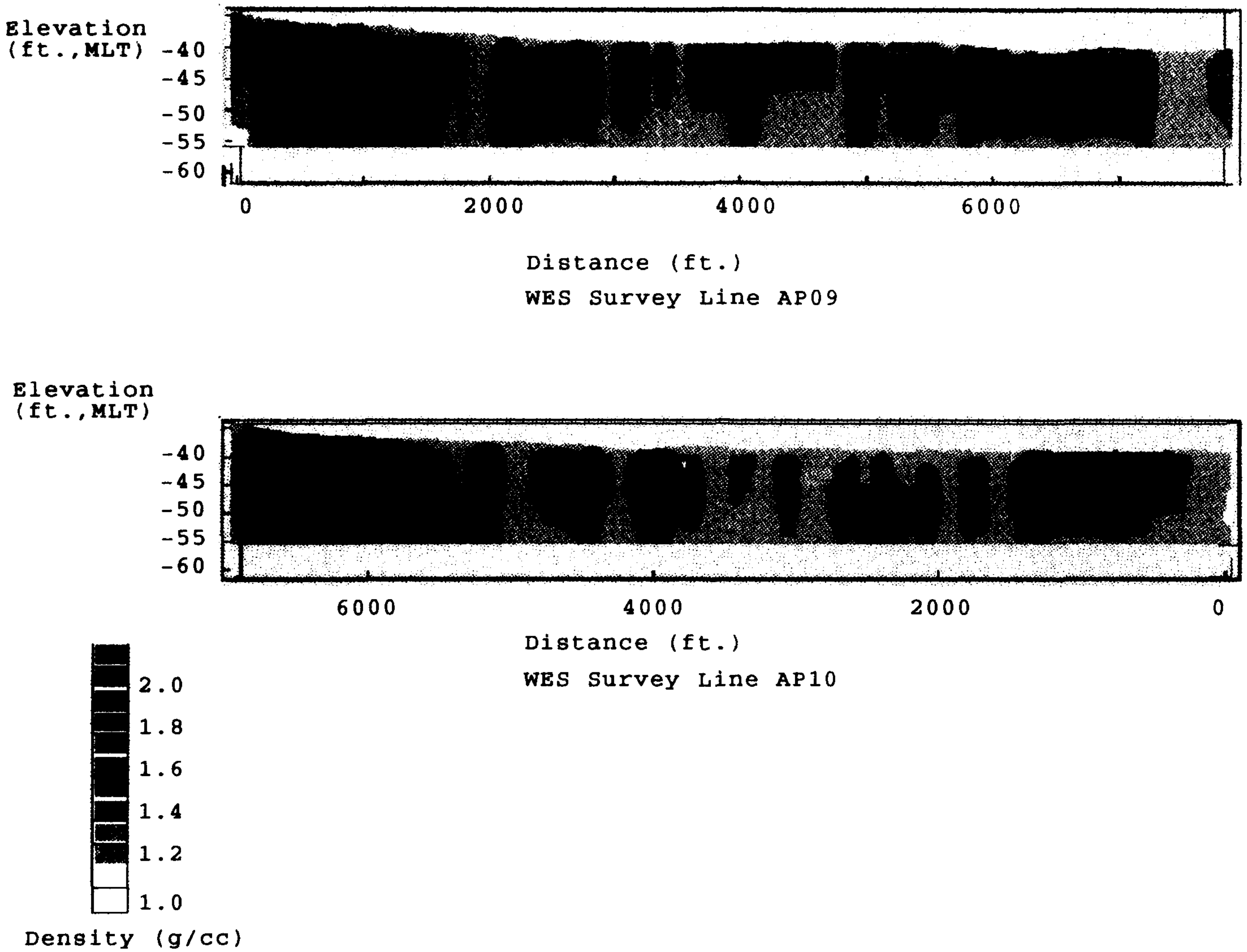

Figure 30. Color-coded density profile along Survey Lines AP09 and AP10, Anchorage Basin

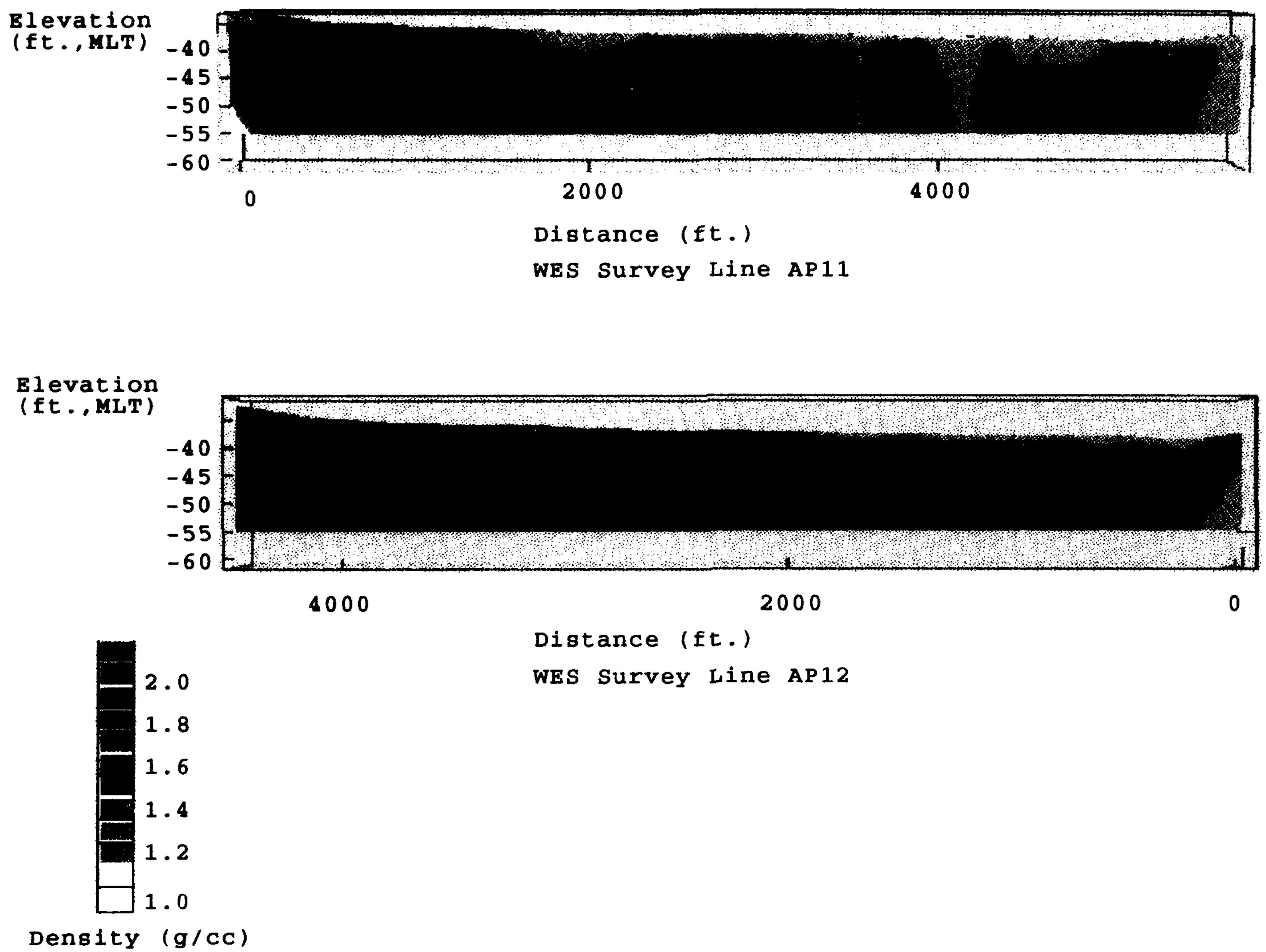

Figure 31. Color-coded density profile along Survey Lines AP11 and AP12, Anchorage Basin

Table 1
Sediment Analysis, WES Cores CERC-1 through CERC-10

Core	Depth (ft)	Moisture Content (%)	Bulk Density (g/cm^3)	Gravel (%)	Sand and Coarse Silt (%)	Fines (%)
CERC-1	0.1	72	1.64	0	9	91
	1.1	69	1.35	0	58	42
	2.2	61	1.23	0	16	84
	4.1	36	1.30	0	22	78
	5.2	33	1.54	0	21	79
CERC-2	0.4	39	1.67	0	54	46
	1.0	30	1.86	0	97	3
	1.3	37	1.54	9	52	39
	2.2	37	1.47	5	70	25
CERC-3	1.0	40	1.61	0	3	97
	2.0	41	1.47	0	9	91
CERC-4	0.1	35	1.86	23	53	24
	0.9	33	1.67	0	66	34
	1.9	37	1.57	0	34	66
CERC-5	0.1	48	1.55	3	22	75
	1.0	44	1.58	0	4	85
	3.0	43	1.55	0	3	97
	4.1	49	1.52	0	4	96
CERC-6	0.1	33	1.55	11	27	62
	1.2	42	1.58	0	6	94
CERC-7	0.8	30	1.68	0	88	12
	1.8	38	1.64	0	58	42
	3.0	52	1.35	1	46	53
CERC-8	0.9	33	1.73	0	80	20
	1.8	34	1.85	0	53	47
CERC-9	grab	27	1.57	0	75	25
CERC-10	0.1	38	1.69	4	14	82
	1.3	35	1.75	0	30	70

Table 2
Sediment Analysis, CESWG Cores 3ST-83 through 3ST-91

Core	Depth (ft)	USCS Soil Class.	Moisture Content (%)	Bulk Density (g/cm^3)	Gravel (%)	Sand and Coarse Silt (%)	Fines (%)
3ST-83	2.0	SP	24		0	96	4
	5.5	CL	45	1.70	0	40	60
	8.0	CL	39	1.79			
	10.0	ML	28		0	24	76
	10.5	SP/SM	29		0	93	7
	13.0	SP	25		0	96	4
	15.5	CH	50	1.73			
	20.5	CH	57	1.64	0	2	98
3ST-84	4.5	SM	33		0	76	24
	11.5	SC	35		5	55	40
	16.5	CL	41	1.85	0	38	62
	19.0	CL	31	1.83	0	72	28
	24.0	CH	68	1.67	0	2	98
3ST-85	2.5	CL	40	1.69	0	32	68
	5.0	SM	39		1	72	27
	7.5	CH	54	1.74			
	12.5	CH	54	1.69	0	2	98
	17.5	CH	62	1.68			91
3ST-86	2.0	SM/SP	31		0	88	12
	4.5	SM	29		2	84	14
	9.5	CL	46	1.73	0	42	58
	12.0	SM	32	1.87	0	80	20
	14.5	SP	28		0	96	4
	19.5	CH	47	1.73	2	4	94
	24.5	CH	56	1.72			
3ST-87	2.0	CL	48		0	16	84
	7.0	CL	39	1.84	0	34	66
	12.0	CL	37	1.84			
	17.0	CH	45	1.71	0	0	100
	22.0	CH	59	1.71			

(Continued)

Table 2 (Concluded)							
Core	Depth (ft)	USCS Soil Class.	Moisture Content (%)	Bulk Density (g/cm^3)	Gravel (%)	Sand and Coarse Silt (%)	Fines (%)
3ST-88	3.5	SM					
	6.5	SM	28		3	79	18
	11.0	SP	27		2	95	3
	16.0	SM/SP	26		0	94	6
	21.0	CH	69	1.68	0	0	100
3ST-89	1.0	CL	48		0	28	72
	7.5	CH	47	1.83			
	12.5	CH	48	1.72	0	2	98
	17.5	CH	67	1.61			
3ST-90	3.0	SM/SP	30		0	88	12
	5.5	SM	38		0	76	24
	13.0	SM	31	1.93	0	52	48
	15.5	SC	37	1.78	0	52	48
	18.0	CH	56	1.68	0	2	98
	20.5	CH	56	1.66			
3ST-91	3.5	SM	43				
	6.0	SM	35		0	64	36
	10.5	SM	26				
	16.0	CH	51	1.74			
	21.0	CH	55	1.66	0	0	100

Table 3
Density Range versus Basic Marine Sediment Classification

Density Range (g/cm^3)	Sediment Classification	Color-Code (for Figures 20-22,26-31)
1.0 - 1.4	clay - silty clay	yellow, orange
1.4 - 1.6	clayey silt - silt	red
1.4 - 1.6	silt - sandy silt	green
> 1.8	sands/stiff clay	blue

Appendix A
Inner Bar Channel Positioning Information

Inner Bar Channel, Galveston, TX
WES Survey Line IP01

Direction: S 84 W

File#	Easting	Northing	Tide (ft)	Elevation (ft, MLT)	Fix Pt.
000	3364987	574437	2.5	-42.3	0813
003	3364638	574386	2.5	-38.6	0814
010	3364290	574357	2.5	-37.2	0816
013	3363944	574339	2.5	-37.0	0818
020	3363601	574303	2.5	-38.6	0820
023	3363253	574253	2.5	-38.2	0821
030	3362904	574209	2.5	-38.6	0823
033	3362550	574202	2.5	-36.9	0825
040	3362217	574153	2.5	-37.4	0827
043	3361868	574109	2.5	-37.6	0828
050	3361520	574062	2.5	-37.9	0830
053	3361172	574057	2.5	-38.4	0832
060	3360835	574002	2.5	-38.5	0834
063	3360490	573980	2.5	-39.3	0835
070	3360156	573935	2.5	-39.6	0837
073	3359807	573904	2.5	-39.5	0839
080	3359473	573862	2.5	-39.2	0840
083	3359128	573847	2.5	-39.7	0842
090	3358793	573804	2.5	-39.5	0844
093	3358446	573759	2.5	-39.4	0846
100	3358113	573716	2.5	-39.7	0847
103	3357770	573677	2.5	-39.9	0849
110	3357412	573657	2.5	-39.8	0851
113	3357082	573607	2.5	-40.0	0852
120	3356735	573583	2.5	-40.3	0854
123	3356386	573538	2.5	-40.0	0856
130	3356044	573506	2.5	-39.7	0858
133	3355694	573476	2.5	-40.1	0859
140	3355350	573431	2.5	-40.2	0861
143	3354985	573396	2.5	-40.6	0863
150	3354635	573362	2.5	-40.2	0865
153	3354285	573324	2.5	-40.7	0866
160	3353928	573267	2.5	-40.2	0868
163	3353579	573227	2.5	-40.1	0870
170	3353230	573199	2.5	-41.2	0872
173	3352879	573154	2.5	-41.0	0874
180	3352538	573148	2.5	-41.6	0875
183	3352217	573085	2.5	-42.4	0877
190	3351883	573025	2.5	-43.4	0879
193	3351557	572968	2.5	-45.1	0880
200	3351233	572882	2.5	-46.9	0882
203	3350903	572788	2.5	-48.7	0884
210	3350573	572708	2.5	-50.4	0885
214	3350152	572755	2.5	-51.5	0887
222	3349733	572777	2.5	-53.0	0889
225	3349387	572794	2.5	-55.3	0891
232	3349066	572789	2.5	-56.6	0893
235	3348734	572775	2.5	-58.7	0894
242	3348429	572689	2.5	-60.0	0896
245	3348085	572691	2.5	-57.9	0898

Inner Bar Channel, Galveston, TX
WES Survey Line IP03

Direction: N 84 E

File#	Easting	Northing	Tide (ft)	Elevation (ft, MLT)	Fix Pt.
000	3347427	572850	2.3	-55.9	0324
003	3347748	572895	2.3	-58.9	0326
010	3348074	572911	2.3	-57.4	0327
013	3348396	572949	2.3	-54.9	0329
020	3348721	572965	2.3	-54.7	0331
023	3349042	573012	2.3	-52.8	0332
030	3349351	573050	2.3	-51.6	0334
033	3349683	573068	2.3	-50.2	0336
040	3350013	573113	2.3	-49.3	0337
043	3350330	573148	2.3	-47.4	0339
050	3350660	573173	2.3	-47.1	0340
053	3350983	573209	2.3	-45.4	0342
060	3351310	573241	2.3	-44.1	0344
064	3351739	573289	2.3	-42.7	0346
070	3351970	573314	2.3	-42.5	0347
072	3352178	573319	2.3	-41.0	0348
075	3352509	573362	2.3	-41.6	0350
082	3352833	573397	2.3	-40.8	0351
085	3353165	573420	2.3	-40.8	0353
092	3353488	573458	2.3	-41.1	0355
095	3353828	573484	2.3	-41.0	0356
102	3354151	573527	2.3	-40.9	0358
105	3354480	573550	2.3	-40.6	0360
112	3354806	573594	2.3	-41.0	0361
115	3355138	573622	2.3	-41.0	0363
122	3355469	573660	2.3	-41.2	0365
125	3355794	573687	2.3	-41.2	0366
132	3356122	573730	2.3	-41.3	0368
135	3356454	573783	2.3	-41.2	0370
142	3356780	573799	2.3	-40.9	0371
145	3357109	573842	2.3	-40.4	0373
152	3357443	573854	2.3	-40.7	0375
155	3357774	573896	2.3	-41.1	0376
162	3358103	573946	2.3	-41.2	0378
165	3358439	573982	2.3	-40.9	0380
172	3358767	574016	2.3	-40.2	0381
175	3359084	574042	2.3	-40.4	0383
182	3359415	574073	2.3	-40.9	0384
185	3359738	574098	2.3	-41.0	0386
192	3360070	574139	2.3	-41.0	0388
195	3360392	574175	2.3	-40.8	0389
202	3360717	574200	2.3	-40.4	0391
205	3361054	574232	2.3	-40.3	0393
212	3361373	574273	2.3	-40.2	0394
215	3361695	574306	2.3	-40.0	0396
222	3362018	574330	2.3	-40.2	0398
225	3362334	574344	2.3	-39.6	0399
232	3362634	574403	2.3	-39.9	0401
235	3362953	574451	2.3	-40.6	0402

Inner Bar Channel, Galveston, TX
WES Survey Line IP03 (Continued)

Direction: N 84 E

File#	Easting	Northing	Tide (ft)	Elevation (ft, MLT)	Fix Pt.
242	3363270	574476	2.3	-43.1	0404
245	3363591	574485	2.3	-41.6	0405
252	3363901	574515	2.3	-40.5	0407
255	3364226	574560	2.3	-41.5	0409
262	3364530	574578	2.3	-43.0	0410
265	3364838	574632	2.3	-45.9	0412

Inner Bar Channel, Galveston, TX
WES Survey Line IP06

Direction: S 84 W

File#	Easting	Northing	Tide (ft)	Elevation (ft, MLT)	Fix Pt.
000	3365040	574811	2.3	-50.7	0624
003	3364711	574776	2.3	-48.7	0626
010	3364368	574743	2.3	-45.4	0628
013	3364028	574693	2.3	-44.3	0629
020	3363684	574673	2.3	-42.9	0631
023	3363329	574618	2.3	-42.7	0633
030	3362980	574585	2.3	-42.0	0635
033	3362633	574547	2.3	-42.0	0636
040	3362277	574510	2.3	-42.2	0638
043	3361927	574485	2.3	-42.2	0640
050	3361572	574436	2.3	-42.0	0642
053	3361223	574402	2.3	-42.3	0643
060	3360876	574371	2.3	-42.5	0645
063	3360526	574338	2.3	-42.3	0647
070	3360172	574286	2.3	-42.4	0649
073	3359823	574258	2.3	-42.3	0650
080	3359466	574224	2.3	-42.4	0652
083	3359110	574186	2.3	-42.3	0654
090	3358759	574158	2.4	-42.5	0656
093	3358406	574098	2.4	-42.4	0658
100	3358050	574083	2.4	-42.7	0659
103	3357699	574052	2.4	-42.6	0661
110	3357351	574010	2.4	-41.8	0663
113	3356978	573974	2.4	-42.2	0665
120	3356623	573926	2.4	-42.0	0667
123	3356274	573895	2.4	-42.0	0668
130	3355903	573849	2.4	-41.9	0670
133	3355545	573828	2.4	-42.1	0672
140	3355197	573783	2.4	-42.3	0674
143	3354840	573753	2.4	-42.2	0676
150	3354486	573696	2.4	-42.1	0677
153	3354120	573672	2.4	-41.8	0679

Inner Bar Channel, Galveston, TX
WES Survey Line IP06 (Continued)

Direction: S 84 W

File#	Easting	Northing	Tide (ft)	Elevation (ft, MLT)	Fix Pt.
160	3353773	573617	2.4	-42.0	0681
163	3353427	573581	2.4	-42.5	0683
170	3353078	573562	2.4	-40.7	0684
173	3352722	573530	2.5	-41.7	0686
180	3352440	573496	2.5	-42.3	0688
183	3351962	573430	2.5	-42.8	0689
190	3351623	573404	2.5	-43.0	0691
193	3351272	573370	2.5	-44.0	0692
200	3350910	573345	2.5	-44.6	0694
203	3350556	573290	2.5	-45.8	0696
210	3350189	573275	2.5	-47.8	0698
213	3349840	573222	2.5	-47.9	0700
220	3349492	573189	2.5	-49.0	0701
223	3349163	573157	2.5	-50.2	0703
230	3348824	573123	2.5	-49.7	0705
233	3348498	573089	2.5	-49.7	0706
240	3348151	573068	2.5	-50.2	0708

Inner Bar Channel, Galveston, TX
WES Survey Line IP04

Direction: S 84 W

File#	Easting	Northing	Tide (ft)	Elevation (ft, MLT)	Fix Pt.
003	3364956	574962	2.3	-54.1	0425
010	3364621	574925	2.3	-52.0	0426
014	3364182	574848	2.3	-47.0	0428
021	3363850	574845	2.3	-46.7	0430
024	3363526	574810	2.3	-44.7	0432
030	3363212	574754	2.3	-43.8	0433
034	3362879	574756	2.3	-43.5	0435
041	3362558	574694	2.3	-43.1	0437
044	3362226	574672	2.3	-42.9	0438
051	3361897	574612	2.3	-43.2	0440
054	3361564	574595	2.3	-42.6	0442
061	3361238	574561	2.3	-42.8	0443
064	3360907	574533	2.3	-42.5	0445
071	3360578	574484	2.3	-42.6	0447
074	3360245	574466	2.3	-42.3	0448
081	3359914	574430	2.3	-42.0	0450
084	3359586	574390	2.3	-41.9	0452
091	3359259	574362	2.3	-42.0	0453
094	3358929	574313	2.3	-42.5	0455
101	3358600	574293	2.3	-41.7	0457
104	3358282	574238	2.3	-42.2	0458

Inner Bar Channel, Galveston, TX
WES Survey Line IP04 (Continued)

Direction: S 84 W

File#	Easting	Northing	Tide (ft)	Elevation (ft, MLT)	Fix Pt.
111	3357946	574199	2.3	-41.7	0460
114	3357608	574168	2.3	-41.7	0462
121	3357280	574121	2.3	-41.4	0463
124	3356947	574110	2.3	-41.3	0465
131	3356611	574083	2.3	-41.1	0467
134	3356282	574057	2.3	-41.4	0468
141	3355948	573985	2.3	-41.0	0470
144	3355604	573966	2.3	-40.6	0472
151	3355266	573921	2.3	-40.0	0473
154	3354934	573902	2.3	-41.3	0475
161	3354545	573861	2.3	-40.1	0477
164	3354268	573832	2.3	-39.8	0479
171	3353932	573784	2.3	-40.2	0481
174	3353587	573740	2.3	-39.5	0483
181	3353247	573728	2.3	-39.0	0484
185	3352797	573686	2.3	-39.3	0487
192	3352458	573625	2.3	-39.8	0488
195	3352114	573599	2.3	-39.9	0490
202	3351765	573598	2.3	-39.3	0492
205	3351424	573518	2.3	-41.3	0494
212	3351084	573513	2.3	-44.9	0495
215	3350746	573485	2.3	-42.3	0497
222	3350403	573430	2.3	-43.5	0499
225	3350062	573374	2.3	-45.0	0500
232	3349716	573361	2.3	-44.4	0502
235	3349371	573332	2.3	-45.5	0504
242	3349031	573271	2.3	-46.9	0506
245	3348676	573259	2.3	-44.7	0507
252	3348333	573214	2.3	-45.0	0509
255	3347989	573172	2.3	-46.1	0511

Inner Bar Channel, Galveston, TX
WES Survey Line IP05

Direction: N 84 E

File#	Easting	Northing	Tide (ft)	Elevation (ft, MLT)	Fix Pt.
000	3347654	573242	2.3	-48.8	0522
003	3347769	573286	2.3	-46.9	0523
010	3348339	573343	2.3	-46.4	0525
013	3348688	573371	2.3	-46.5	0527
020	3349044	573408	2.3	-46.5	0529
023	3349402	573437	2.3	-46.6	0530
030	3349759	573473	2.3	-45.3	0532
033	3350113	573521	2.3	-45.5	0534
040	3350477	573542	2.3	-44.9	0536
043	3350829	573572	2.3	-44.7	0537
050	3351175	573620	2.3	-44.1	0539
053	3351534	573644	2.3	-43.0	0541
060	3351866	573693	2.3	-42.7	0543
063	3352223	573697	2.3	-43.1	0544
070	3352576	573767	2.3	-42.3	0546
073	3352934	573789	2.3	-41.6	0548
080	3353284	573814	2.3	-43.1	0550
083	3353633	573869	2.3	-42.5	0552
090	3353986	573933	2.3	-43.5	0553
093	3354341	573954	2.3	-43.9	0555
100	3354699	573980	2.3	-39.4	0557
103	3355054	574032	2.3	-40.4	0559
110	3355412	574052	2.3	-39.6	0561
113	3355772	574076	2.3	-40.5	0562
120	3356125	574126	2.3	-40.2	0564
123	3356489	574168	2.3	-40.2	0566
130	3356853	574194	2.3	-42.0	0568
133	3357216	574228	2.3	-41.0	0570
140	3357580	574264	2.3	-41.6	0571
143	3357925	574305	2.3	-42.7	0573
150	3358288	574360	2.3	-42.2	0575
153	3358643	574402	2.3	-42.2	0577
160	3359020	574423	2.3	-42.2	0579
163	3359378	574442	2.3	-42.3	0580
170	3359713	574512	2.3	-42.6	0582
173	3360069	574541	2.3	-41.6	0584
180	3360419	574566	2.3	-42.2	0586
183	3360775	574611	2.3	-43.0	0587
190	3361130	574642	2.3	-42.4	0589
193	3361488	574680	2.3	-43.1	0591
200	3361836	574733	2.3	-42.6	0593
203	3362199	574774	2.3	-43.6	0595
210	3362553	574798	2.3	-44.4	0596
220	3363264	574847	2.3	-44.6	0600
223	3363621	574874	2.3	-45.6	0602
230	3363975	574933	2.3	-48.1	0604
233	3364321	574969	2.3	-51.0	0605

Inner Bar Channel, Galveston, TX
WES Survey Line IP07

Direction: N 84 E

File#	Easting	Northing	Tide (ft)	Elevation (ft, MLT)	Fix Pt.
000	3347634	573345	2.5	-42.2	0713
003	3348027	573388	2.5	-40.5	0715
010	3348432	573420	2.5	-40.4	0717
020	3349239	573520	2.5	-39.6	0722
023	3349642	573548	2.5	-39.9	0724
030	3350050	573582	2.5	-38.4	0726
033	3350428	573640	2.5	-37.9	0728
040	3350814	573662	2.5	-38.0	0729
043	3351195	573728	2.5	-36.3	0731
050	3351576	573765	2.5	-36.0	0733
053	3351972	573796	2.5	-36.1	0735
060	3352343	573860	2.5	-34.9	0737
063	3352750	573885	2.5	-36.6	0739
070	3353125	573899	2.5	-36.9	0741
073	3353512	573954	2.5	-36.3	0743
080	3353912	573973	2.5	-38.2	0745
093	3354981	574126	2.5	-41.7	0750
100	3355374	574154	2.5	-39.3	0752
103	3355772	574186	2.5	-39.9	0754
110	3356161	574227	2.5	-40.1	0756
113	3356558	574282	2.5	-40.7	0758
120	3356946	574325	2.5	-42.1	0760
123	3357356	574350	2.5	-42.1	0762
130	3357735	574389	2.5	-43.2	0764
133	3358128	574460	2.5	-42.0	0766
140	3358520	574491	2.5	-42.5	0768
143	3358907	574538	2.5	-42.8	0770
150	3359299	574565	2.5	-43.0	0772
153	3359705	574607	2.5	-42.4	0774
160	3360101	574669	2.5	-42.7	0776
163	3360499	574701	2.5	-42.6	0778
170	3360889	574731	2.5	-42.9	0780
173	3361290	574756	2.5	-42.8	0782
180	3361685	574810	2.5	-44.2	0784
183	3362084	574842	2.5	-43.1	0786
190	3362481	574889	2.5	-44.1	0788
193	3362879	574930	2.5	-45.5	0790
200	3363269	574962	2.5	-45.5	0792
203	3363666	575011	2.5	-47.6	0794
210	3364065	575045	2.5	-49.6	0796
213	3364461	575103	2.5	-52.5	0798

Appendix B
Anchorage Basin Positioning Information

Anchorage Basin, Galveston, TX
WES Survey Line AP01

Direction: N 84 E

File#	Easting	Northing	Tide (ft)	Elevation (ft, MLT)	Fix Pt.
000	3354778	574270	2.2	-37.5	0442
003	3355120	574278	2.2	-38.1	0444
010	3355496	574310	2.2	-38.3	0446
013	3355878	574343	2.2	-38.7	0448
020	3356258	574369	2.2	-39.7	0450
023	3356626	574427	2.2	-40.3	0451
030	3356979	574474	2.2	-40.4	0453
033	3357326	574508	2.2	-41.6	0455
040	3357695	574546	2.2	-41.5	0457
043	3358034	574590	2.2	-41.9	0459
050	3358372	574616	2.2	-41.9	0460
053	3358717	574662	2.2	-41.5	0462
060	3359077	574653	2.2	-43.1	0464
063	3359412	574706	2.2	-42.5	0465
070	3359751	574739	2.2	-42.2	0467
073	3360092	574795	2.2	-42.8	0469
080	3360440	574830	2.2	-42.3	0471
083	3360789	574859	2.2	-43.0	0472
090	3361130	574900	2.2	-42.7	0474
093	3361446	574925	2.2	-42.8	0476
100	3361759	574957	2.2	-42.6	0477
103	3362062	575001	2.2	-43.0	0479
110	3362368	575031	2.2	-43.4	0480
113	3362673	575052	2.2	-43.8	0482
120	3362984	575086	2.2	-45.0	0483
123	3363294	575123	2.2	-46.3	0485
130	3363594	575146	2.2	-47.5	0487
133	3363892	575178	2.2	-48.2	0488
140	3364201	575213	2.2	-49.7	0490
143	3364504	575238	2.2	-50.9	0491
150	3364803	575265	2.2	-52.1	0493
153	3365100	575309	2.2	-48.4	0494
160	3365405	575345	2.2	-46.3	0496
164	3365800	575380	2.2	-47.1	0498

Anchorage Basin, Galveston, TX
WES Survey Line AP02

Direction: S 84 W

File#	Easting	Northing	Tide (ft)	Elevation (ft, MLT)	Fix Pt.
000	3366345	575705	1.6	-43.9	0090
003	3366120	575668	1.6	-44.7	0091
010	3365886	575641	1.6	-43.6	0092
013	3365640	575653	1.6	-44.3	0093
020	3365407	575607	1.6	-45.2	0094
023	3365184	575557	1.6	-45.3	0095
030	3364942	575558	1.6	-46.4	0097
033	3364699	575522	1.6	-47.3	0098
040	3364448	575489	1.6	-48.1	0099
043	3364196	575474	1.6	-49.1	0100
050	3363940	575427	1.6	-48.5	0102
053	3363688	575397	1.6	-47.8	0103
060	3363434	575390	1.6	-46.6	0104
063	3363181	575379	1.6	-46.0	0105
070	3362937	575359	1.6	-46.0	0107
073	3362691	575320	1.6	-44.6	0108
080	3362439	575292	1.6	-43.4	0109
083	3362188	575278	1.6	-43.4	0110
090	3361944	575255	1.6	-43.2	0112
093	3361688	575220	1.6	-43.4	0113
100	3361439	575164	1.6	-42.4	0114
103	3361184	575147	1.6	-42.3	0115
110	3360932	575148	1.6	-41.7	0117
113	3360681	575110	1.6	-42.3	0118
120	3360439	575072	1.6	-41.9	0119
123	3360192	575047	1.6	-42.1	0120
130	3359937	575028	1.6	-41.7	0122
133	3359686	575009	1.6	-41.8	0123
140	3359467	575028	1.6	-40.8	0124
143	3359258	574994	1.6	-41.4	0125
150	3359055	574950	1.6	-41.1	0126
153	3358849	574906	1.6	-40.8	0127
160	3358642	574887	1.6	-40.4	0128
163	3358419	574865	1.6	-39.9	0129
170	3358207	574843	1.6	-39.8	0130
173	3357992	574821	1.6	-39.1	0132
180	3357781	574798	1.6	-38.6	0133
183	3357566	574784	1.6	-38.9	0134
190	3357345	574759	1.6	-39.0	0135
193	3357130	574735	1.6	-39.1	0136
200	3356902	574715	1.6	-38.6	0137
203	3356692	574678	1.6	-38.5	0138
210	3356471	574667	1.6	-38.1	0139
213	3356262	574646	1.6	-37.6	0140
220	3356046	574623	1.6	-37.4	0141
223	3355834	574593	1.6	-37.3	0142
230	3355617	574583	1.6	-36.6	0143
233	3355399	574564	1.6	-36.5	0145
240	3355197	574492	1.6	-36.2	0146
243	3354990	574414	1.6	-36.4	0147

Anchorage Basin, Galveston, TX
WES Survey Line AP03

Direction: N 84 E

File#	Easting	Northing	Tide (ft)	Elevation (ft, MLT)	Fix Pt.
030	3356830	574952	1.5	-38.0	0173
033	3357209	574993	1.5	-38.2	0175
040	3357564	575024	1.5	-37.8	0176
043	3357926	575067	1.5	-38.7	0178
050	3358297	575098	1.5	-39.1	0180
053	3358641	575130	1.5	-40.1	0182
060	3359008	575187	1.5	-39.7	0184
063	3359373	575225	1.5	-39.7	0186
070	3359752	575246	1.5	-40.2	0187
073	3360120	575292	1.5	-40.8	0189
080	3360494	575343	1.5	-40.5	0191
083	3360868	575354	1.5	-41.5	0193
090	3361235	575406	1.5	-41.9	0195
093	3361598	575434	1.5	-44.0	0197
100	3361970	575465	1.5	-43.6	0199
103	3362339	575511	1.5	-44.4	0200
110	3362718	575549	1.5	-45.9	0202
113	3363092	575592	1.5	-47.4	0204
120	3363470	575642	1.5	-48.9	0206
123	3363841	575668	1.5	-49.3	0208
130	3364208	575710	1.5	-47.9	0210
133	3364578	575758	1.5	-47.5	0212
140	3364934	575787	1.5	-47.2	0214
143	3365301	575809	1.5	-45.6	0215
150	3365659	575861	1.5	-43.5	0217

Anchorage Basin, Galveston, TX
WES Survey Line AP04

Direction: S 84 W

File#	Easting	Northing	Tide (ft)	Elevation (ft, MLT)	Fix Pt.
002	3365529	576120	1.4	-42.8	0230
005	3365335	576093	1.4	-42.5	0231
012	3365144	576070	1.4	-43.4	0232
015	3364946	576051	1.4	-44.1	0233
022	3364755	576021	1.4	-44.5	0234
025	3364564	575999	1.4	-45.2	0235
032	3364364	575993	1.4	-45.7	0236
035	3364167	575958	1.4	-45.7	0237
042	3363976	575944	1.4	-46.1	0238
045	3363772	575927	1.4	-46.9	0239
052	3363568	575907	1.4	-47.0	0240
055	3363370	575884	1.4	-47.0	0241
062	3363171	575865	1.4	-46.8	0242
065	3362971	575846	1.4	-46.7	0243
072	3362767	575821	1.4	-46.5	0244
075	3362564	575796	1.4	-45.1	0245
082	3362368	575772	1.4	-45.0	0246
085	3362175	575766	1.4	-45.0	0247
092	3361971	575754	1.4	-44.7	0248
095	3361772	575728	1.4	-43.6	0249
102	3361573	575695	1.4	-43.3	0250
105	3361368	575681	1.4	-43.9	0251
112	3361166	575663	1.4	-44.1	0252
115	3360965	575622	1.4	-43.2	0253
122	3360773	575613	1.4	-42.3	0254
125	3360584	575624	1.4	-41.8	0255
132	3360392	575588	1.4	-40.5	0256
135	3360204	575538	1.4	-40.3	0257
142	3360004	575538	1.4	-39.9	0258
145	3359799	575507	1.4	-39.5	0259
152	3359595	575489	1.4	-39.9	0260
155	3359391	575476	1.4	-39.4	0261
162	3359192	575439	1.4	-39.7	0262
165	3358992	575427	1.4	-39.6	0263
172	3358808	575380	1.4	-39.4	0264
175	3358603	575405	1.4	-39.6	0265
182	3358400	575375	1.4	-39.5	0266
185	3358189	575338	1.4	-39.1	0267
192	3357972	575322	1.4	-38.7	0268
195	3357754	575295	1.4	-39.0	0269
202	3357530	575276	1.4	-38.7	0269
205	3357299	575257	1.4	-38.3	0272
212	3357075	575238	1.4	-38.0	0272
215	3356851	575213	1.4	-38.2	0274
222	3356622	575176	1.4	-37.3	0275
225	3356382	575165	1.4	-37.1	0276
232	3356149	575127	1.4	-37.1	0278
235	3355900	575103	1.4	-36.9	0279
242	3355663	575084	1.4	-36.3	0280
245	3355421	575062	1.4	-35.4	0281
252	3355178	575035	1.4	-33.7	0282

Anchorage Basin, Galveston, TX
WES Survey Line AP05

Direction: N 84 E

File#	Easting	Northing	Tide (ft)	Elevation (ft, MLT)	Fix Pt.
000	3355494	575319	2.5	-35.6	0055
003	3355710	575335	2.5	-36.6	0056
010	3355920	575358	2.5	-37.1	0057
013	3356134	575388	2.5	-37.8	0059
020	3356348	575405	2.5	-38.3	0060
023	3356567	575419	2.5	-38.7	0061
030	3356780	575459	2.5	-39.0	0062
033	3356978	575473	2.5	-39.5	0063
040	3357196	575485	2.5	-39.4	0064
043	3357392	575525	2.5	-39.2	0065
050	3357581	575538	2.5	-39.4	0066
053	3357793	575548	2.5	-39.8	0067
060	3358007	575587	2.5	-39.8	0068
063	3358230	575596	2.5	-39.5	0069
070	3358451	575619	2.5	-39.9	0070
073	3358665	575657	2.5	-40.3	0071
080	3358880	575671	2.5	-40.0	0072
083	3359088	575675	2.5	-40.6	0073
090	3359302	575708	2.5	-40.2	0074
093	3359502	575731	2.5	-39.6	0075
100	3359704	575755	2.5	-39.9	0076
103	3359910	575789	2.5	-40.2	0078
110	3360124	575796	2.5	-41.5	0079
113	3360345	575805	2.5	-42.6	0080
120	3360557	575823	2.5	-42.8	0081
123	3360772	575856	2.5	-43.4	0082
130	3360976	575890	2.5	-42.7	0083
133	3361186	575909	2.5	-43.8	0084
140	3361400	575935	2.5	-45.0	0085
143	3361606	575953	2.5	-44.9	0086
150	3361815	575971	2.5	-45.6	0087
153	3362018	576001	2.5	-45.0	0088
160	3362230	576016	2.5	-45.4	0089
163	3362445	576033	2.5	-46.2	0090
170	3362654	576072	2.5	-46.4	0091
173	3362864	576086	2.5	-46.0	0092
180	3363085	576084	2.5	-45.7	0093
183	3363307	576110	2.5	-45.7	0095
190	3363534	576162	2.5	-44.4	0096
193	3363765	576167	2.5	-44.0	0097
200	3364006	576203	2.5	-43.0	0098
203	3364249	576242	2.5	-43.2	0099
210	3364483	576234	2.5	-43.3	0100
213	3364718	576256	2.5	-43.0	0102
220	3364951	576297	2.5	-43.7	0103
223	3365200	576314	2.5	-44.6	0104
230	3365437	576336	2.5	-44.9	0105

Anchorage Basin, Galveston, TX
WES Survey Line AP06

Direction: S 84 W

File#	Easting	Northing	Tide (ft)	Elevation (ft, MLT)	Fix Pt.
000	3365132	576564	2.4	-44.9	0111
003	3364835	576570	2.4	-41.4	0113
010	3364522	576533	2.4	-44.2	0114
013	3364193	576488	2.4	-42.9	0116
020	3363852	576445	2.4	-42.7	0118
023	3363508	576380	2.4	-42.6	0119
030	3363145	576378	2.4	-43.6	0121
033	3362787	576318	2.4	-44.0	0123
040	3362426	576304	2.4	-44.5	0125
043	3362066	576258	2.4	-44.7	0127
050	3361692	576224	2.4	-44.9	0128
053	3361300	576194	2.4	-44.8	0130
060	3360928	576146	2.4	-44.5	0132
063	3360549	576099	2.4	-43.7	0134
070	3360184	576033	2.4	-42.5	0136
073	3359803	576018	2.4	-40.6	0138
080	3359416	575971	2.4	-39.2	0140
083	3359040	575921	2.4	-38.7	0142
090	3358657	575895	2.4	-39.8	0144
093	3358289	575839	2.4	-40.0	0146
100	3357915	575802	2.4	-39.8	0147
103	3357552	575790	2.4	-39.1	0149
110	3357177	575725	2.4	-39.4	0151
113	3356792	575681	2.4	-38.2	0153
120	3356430	575673	2.4	-37.9	0155
123	3356062	575613	2.4	-37.4	0157
130	3355693	575573	2.4	-36.3	0159

Anchorage Basin, Galveston, TX
WES Survey Line AP07

Direction: N 84 E

File#	Easting	Northing	Tide (ft)	Elevation (ft, MLT)	Fix Pt.
000	3355234	575798	2.3	-33.9	0166
003	3355402	575821	2.3	-34.4	0167
010	3355570	575841	2.3	-35.3	0168
013	3355740	575852	2.3	-36.2	0169
020	3355931	575869	2.3	-36.6	0170
023	3356138	575870	2.3	-36.9	0171
030	3356324	575900	2.3	-37.1	0172
033	3356519	575925	2.3	-37.5	0173
040	3356717	575953	2.3	-38.0	0174
043	3356916	575970	2.3	-38.2	0175
050	3357109	575985	2.3	-38.4	0176
053	3357320	575997	2.3	-38.6	0177
060	3357533	576022	2.3	-38.2	0178
063	3357758	576038	2.3	-38.6	0179
070	3357979	576076	2.3	-39.4	0180
073	3358204	576120	2.3	-39.7	0181
080	3358430	576126	2.3	-39.8	0182
083	3358656	576148	2.3	-40.2	0183
090	3358880	576170	2.3	-39.6	0185
093	3359099	576192	2.3	-39.3	0186
100	3359330	576214	2.3	-40.0	0187
103	3359560	576227	2.3	-39.7	0188
110	3359788	576262	2.3	-40.1	0189
113	3360018	576286	2.3	-40.9	0190
120	3360249	576316	2.3	-41.5	0191
123	3360481	576339	2.3	-42.0	0193
130	3360717	576359	2.3	-42.9	0194
133	3360958	576381	2.3	-43.9	0195
140	3361208	576398	2.3	-43.2	0196
143	3361453	576426	2.3	-43.3	0198
150	3361698	576467	2.3	-43.1	0199
153	3361935	576486	2.3	-43.0	0200
160	3362177	576510	2.3	-42.6	0201
163	3362421	576538	2.3	-42.6	0202
170	3362666	576574	2.3	-42.1	0204
173	3362910	576578	2.3	-42.0	0205
180	3363159	576614	2.3	-42.5	0206
183	3363409	576649	2.3	-42.6	0207
190	3363659	576675	2.3	-42.6	0209
193	3363904	576695	2.3	-42.3	0210

Anchorage Basin, Galveston, TX
WES Survey Line AP08

Direction: S 84 W

File#	Easting	Northing	Tide (ft)	Elevation (ft, MLT)	Fix Pt.
000	3365053	577070	2.3	-42.2	0225
003	3364786	577015	2.3	-43.2	0227
010	3364499	577006	2.3	-41.8	0228
013	3364219	576984	2.3	-40.8	0229
020	3363939	576950	2.3	-41.4	0231
023	3363651	576926	2.3	-40.9	0232
030	3363366	576890	2.3	-41.1	0234
033	3363085	576849	2.3	-39.1	0235
040	3362808	576835	2.3	-41.2	0237
043	3362533	576796	2.3	-41.2	0238
050	3362248	576781	2.3	-40.3	0239
053	3361964	576752	2.3	-40.2	0241
060	3361676	576718	2.3	-40.7	0242
063	3361393	576679	2.3	-40.6	0244
070	3361102	576656	2.3	-40.0	0245
073	3360814	576630	2.3	-39.6	0247
080	3360520	576590	2.3	-39.8	0248
083	3360230	576556	2.3	-40.8	0250
090	3359939	576530	2.3	-41.0	0251
093	3359642	576503	2.3	-40.5	0252
100	3359357	576468	2.3	-40.2	0254
103	3359060	576435	2.3	-40.0	0255
110	3358769	576397	2.3	-39.3	0257
113	3358484	576395	2.3	-39.2	0258
120	3358208	576370	2.3	-39.1	0260
123	3357927	576331	2.3	-38.9	0261
130	3357651	576298	2.3	-38.4	0262
133	3357378	576266	2.3	-37.9	0264
140	3357094	576246	2.3	-37.0	0265
143	3356798	576196	2.3	-37.2	0267
150	3356488	576171	2.3	-36.7	0268
153	3356198	576147	2.3	-36.3	0270
160	3355896	576117	2.3	-35.8	0271
163	3355608	576067	2.3	-34.2	0273

Anchorage Basin, Galveston, TX
WES Survey Line AP09

Direction: N 84 E

File#	Easting	Northing	Tide (ft)	Elevation (ft, MLT)	Fix Pt.
000	3355822	576365	2.2	-34.4	0276
003	3356004	576392	2.2	-35.1	0277
010	3356208	576395	2.2	-35.6	0278
013	3356420	576418	2.2	-36.1	0279
020	3356645	576438	2.2	-36.0	0281
023	3356890	576450	2.2	-36.3	0282
030	3357137	576494	2.2	-36.6	0283
033	3357373	576534	2.2	-37.6	0285
040	3357614	576565	2.2	-37.3	0287
043	3357838	576582	2.2	-37.8	0289
050	3358076	576599	2.2	-38.3	0290
053	3358326	576614	2.2	-38.2	0291
060	3358562	576630	2.2	-38.5	0292
063	3358786	576656	2.2	-38.7	0293
070	3359014	576685	2.2	-38.8	0295
073	3359237	576726	2.2	-39.0	0296
080	3359453	576735	2.2	-39.0	0297
083	3359684	576742	2.2	-38.9	0298
090	3359900	576777	2.2	-39.8	0299
093	3360115	576803	2.2	-38.5	0300
100	3360326	576810	2.2	-38.9	0301
103	3360530	576828	2.2	-38.7	0302
110	3360735	576870	2.2	-39.0	0303
113	3360956	576894	2.2	-38.9	0304
120	3361193	576908	2.2	-38.9	0305
123	3361440	576939	2.2	-39.0	0307
130	3361688	576970	2.2	-39.6	0308
133	3361944	576988	2.2	-40.0	0309
140	3362203	577021	2.2	-40.5	0311
143	3362464	577044	2.2	-40.0	0312
150	3362741	577067	2.2	-39.8	0313
153	3363002	577105	2.2	-40.1	0315
160	3363263	577112	2.2	-40.1	0316
163	3363527	577156	2.2	-40.1	0317

Anchorage Basin, Galveston, TX
WES Survey Line AP10

Direction: S 84 W

File#	Easting	Northing	Tide (ft)	Elevation (ft, MLT)	Fix Pt.
000	3362788	577331	2.2	-38.7	0325
003	3362456	577326	2.2	-38.5	0327
010	3362180	577279	2.2	-38.6	0328
013	3361906	577239	2.2	-38.9	0330
020	3361624	577221	2.2	-38.6	0331
023	3361341	577200	2.2	-38.7	0333
030	3361083	577133	2.2	-38.6	0334
033	3360796	577094	2.2	-38.5	0335
040	3360514	577140	2.2	-38.8	0337
043	3360221	577177	2.2	-38.2	0338
050	3359943	577180	2.2	-38.2	0340
053	3359714	577081	2.2	-38.3	0341
060	3359467	576981	2.2	-38.3	0342
063	3359172	576955	2.2	-37.7	0344
070	3358888	576903	2.2	-38.3	0345
073	3358608	576869	2.2	-38.3	0346
080	3358314	576842	2.2	-37.6	0348
083	3358012	576820	2.2	-37.2	0349
090	3357708	576796	2.2	-37.1	0351
093	3357424	576777	2.2	-36.8	0352
100	3357134	576728	2.2	-36.7	0354
103	3356844	576682	2.2	-36.3	0355
110	3356540	576699	2.2	-35.9	0357
113	3356255	576666	2.2	-35.3	0358
120	3355970	576622	2.2	-34.0	0360

Anchorage Basin, Galveston, TX
WES Survey Line AP11

Direction: N 84 E

File#	Easting	Northing	Tide (ft)	Elevation (ft, MLT)	Fix Pt.
000	3355940	576874	2.2	-32.8	0366
003	3356216	576911	2.2	-34.3	0368
010	3356486	576932	2.2	-35.2	0369
013	3356763	576966	2.2	-35.4	0370
020	3357035	576987	2.2	-35.9	0372
023	3357315	577019	2.2	-36.0	0373
030	3357581	577039	2.2	-36.3	0375
033	3357866	577062	2.2	-36.9	0376
040	3358132	577120	2.2	-36.9	0377
043	3358409	577135	2.2	-37.0	0379
050	3358682	577163	2.2	-37.3	0380
053	3358967	577179	2.2	-37.2	0382
060	3359238	577186	2.2	-37.2	0383
063	3359521	577241	2.2	-37.5	0384
070	3359802	577278	2.2	-37.9	0386
073	3360088	577300	2.2	-37.5	0387
080	3360369	577333	2.2	-37.5	0389
083	3360645	577344	2.2	-38.3	0390
090	3360928	577377	2.2	-38.4	0391

Anchorage Basin, Galveston, TX
WES Survey Line AP12

Direction: S 84 W

File#	Easting	Northing	Tide (ft)	Elevation (ft, MLT)	Fix Pt.
000	3360513	577586	2.2	-37.3	0406
003	3360167	577546	2.2	-37.7	0407
010	3359818	577539	2.2	-37.5	0409
013	3359474	577501	2.2	-37.2	0411
020	3359132	577456	2.2	-37.0	0413
023	3358792	577408	2.2	-36.8	0414
030	3358443	577391	2.2	-36.7	0416
033	3358114	577344	2.2	-36.5	0418
040	3357765	577327	2.2	-36.1	0419
043	3357418	577251	2.2	-35.5	0421
050	3357071	577232	2.2	-35.3	0423
053	3356709	577207	2.2	-34.8	0425
060	3356358	577151	2.2	-33.9	0426

REPORT DOCUMENTATION PAGE

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1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	August 1994	Final report

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A Waterborne Seismic Reflection Survey of the Inner Bar Channel and Anchorage Basin, Galveston, Texas

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6. AUTHOR(S)
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3909 Halls Ferry Road
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Galveston, TX 77553

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12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

A waterborne seismic reflection investigation of the Inner Bar Channel and Anchorage Basin near Galveston, TX, is reported. The geophysical study was performed to characterize and quantify bottom and subbottom sediments in support of proposed maintenance dredging of the project areas. Two high resolution subbottom profiling systems were used to meet the primary project objectives. The survey results provide estimates of the sediment density, material type, and volume of material to be removed through dredging. In addition, the information supplements previously obtained soil borings by providing continuous profile line coverage of the subbottom sediments in each project area.

14. SUBJECT TERMS
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Geophysical methods
Seismic reflection
Waterborne geophysics

15. NUMBER OF PAGES
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Prescribed by ANSI Std Z39-18
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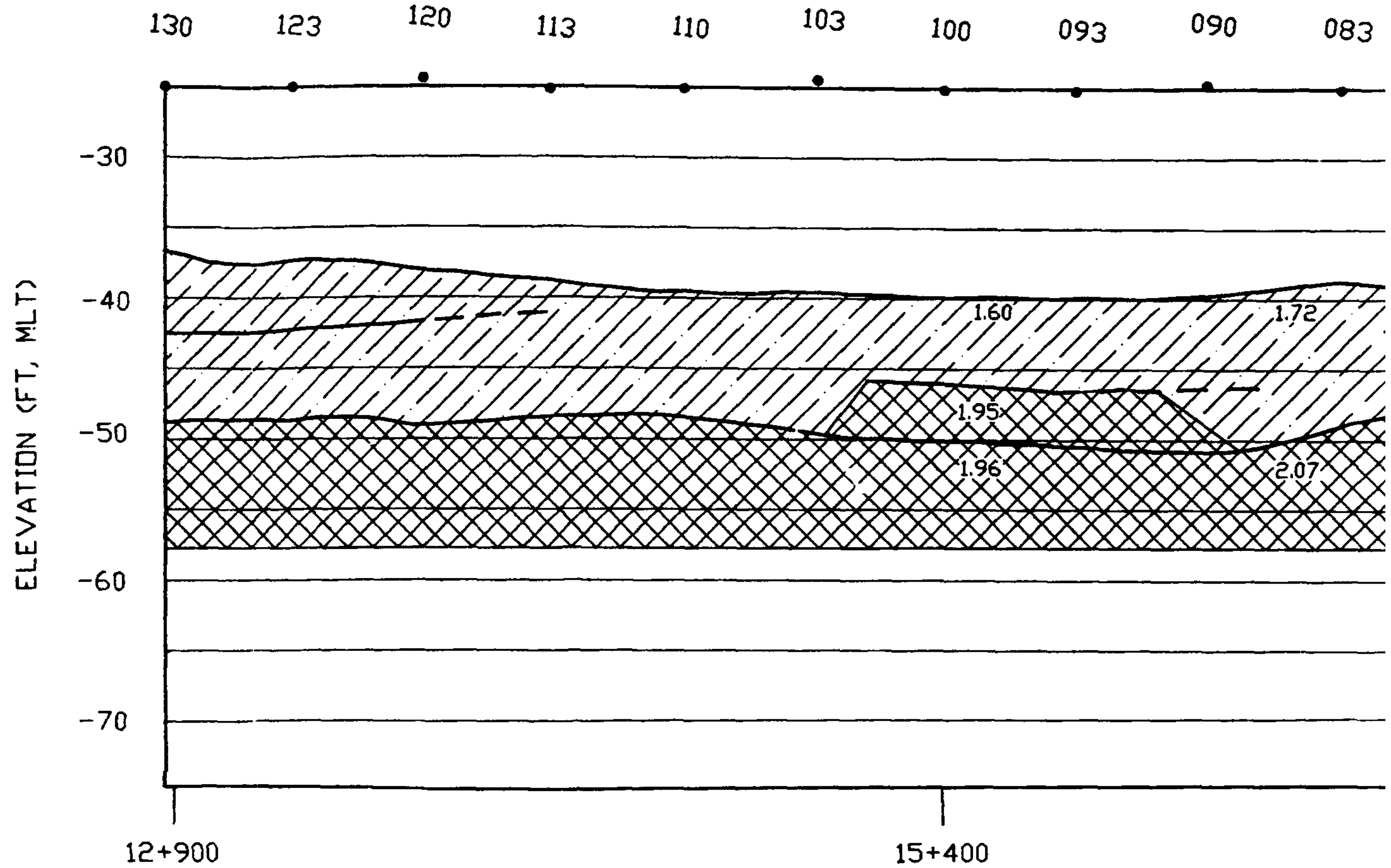

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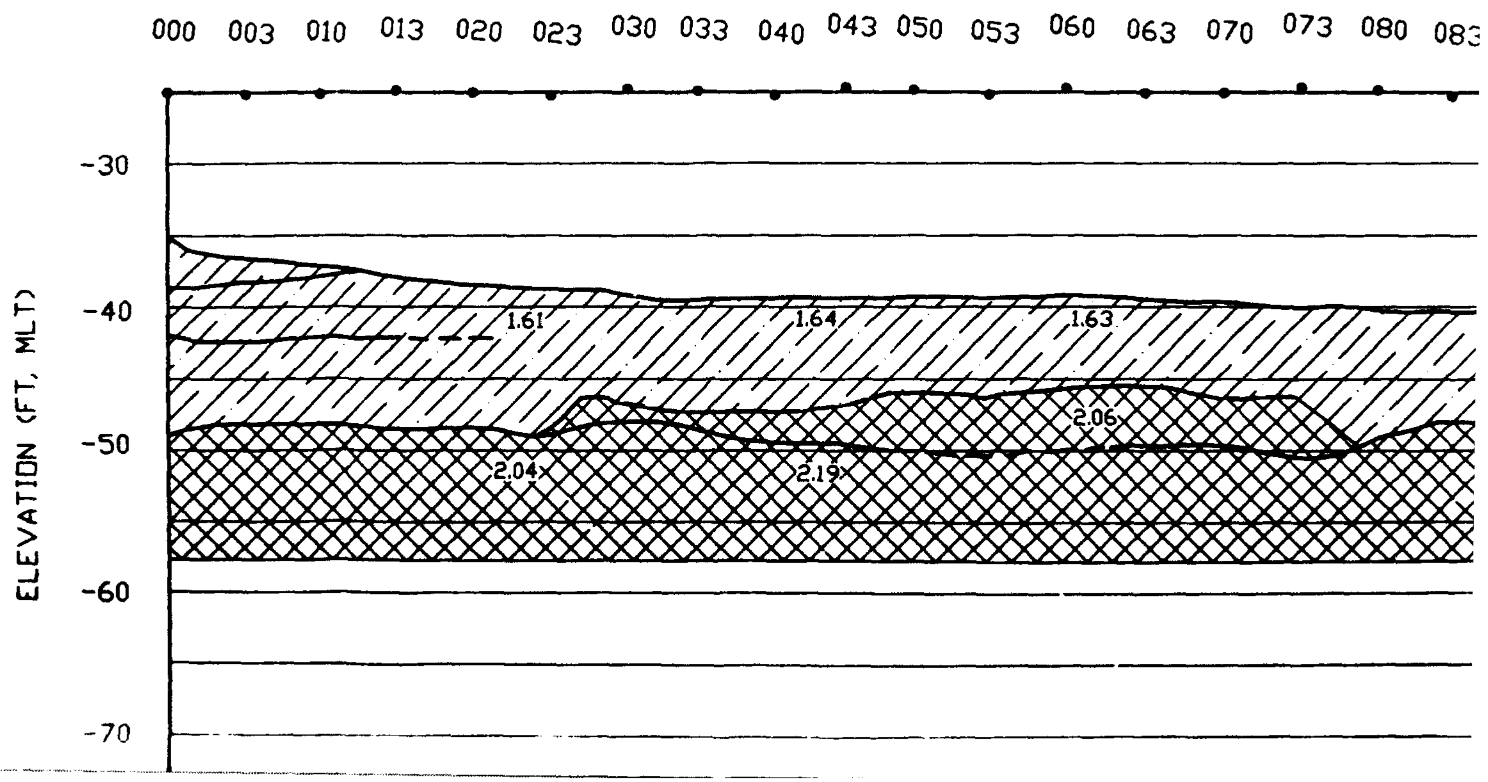

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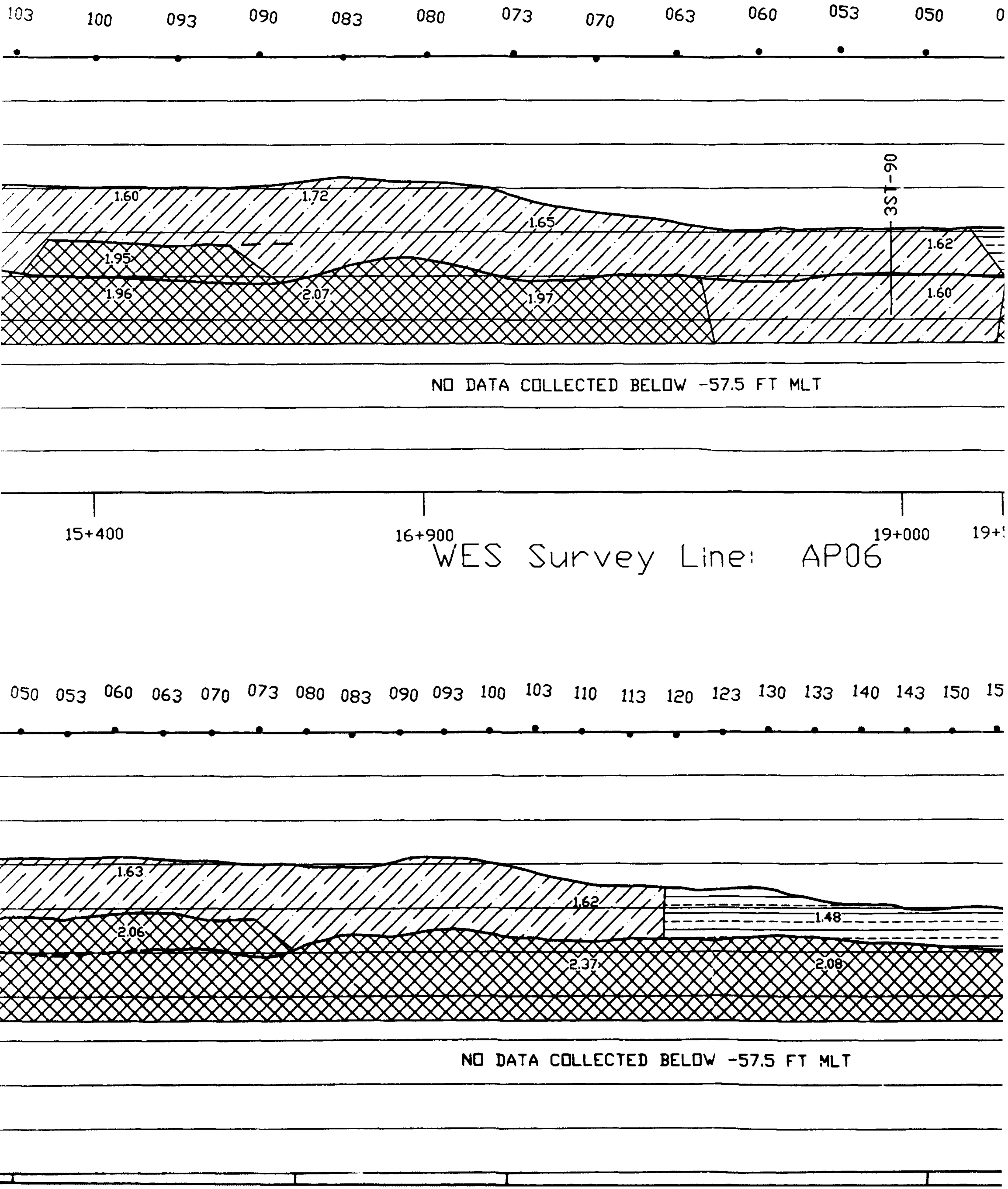
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16+900
19+000
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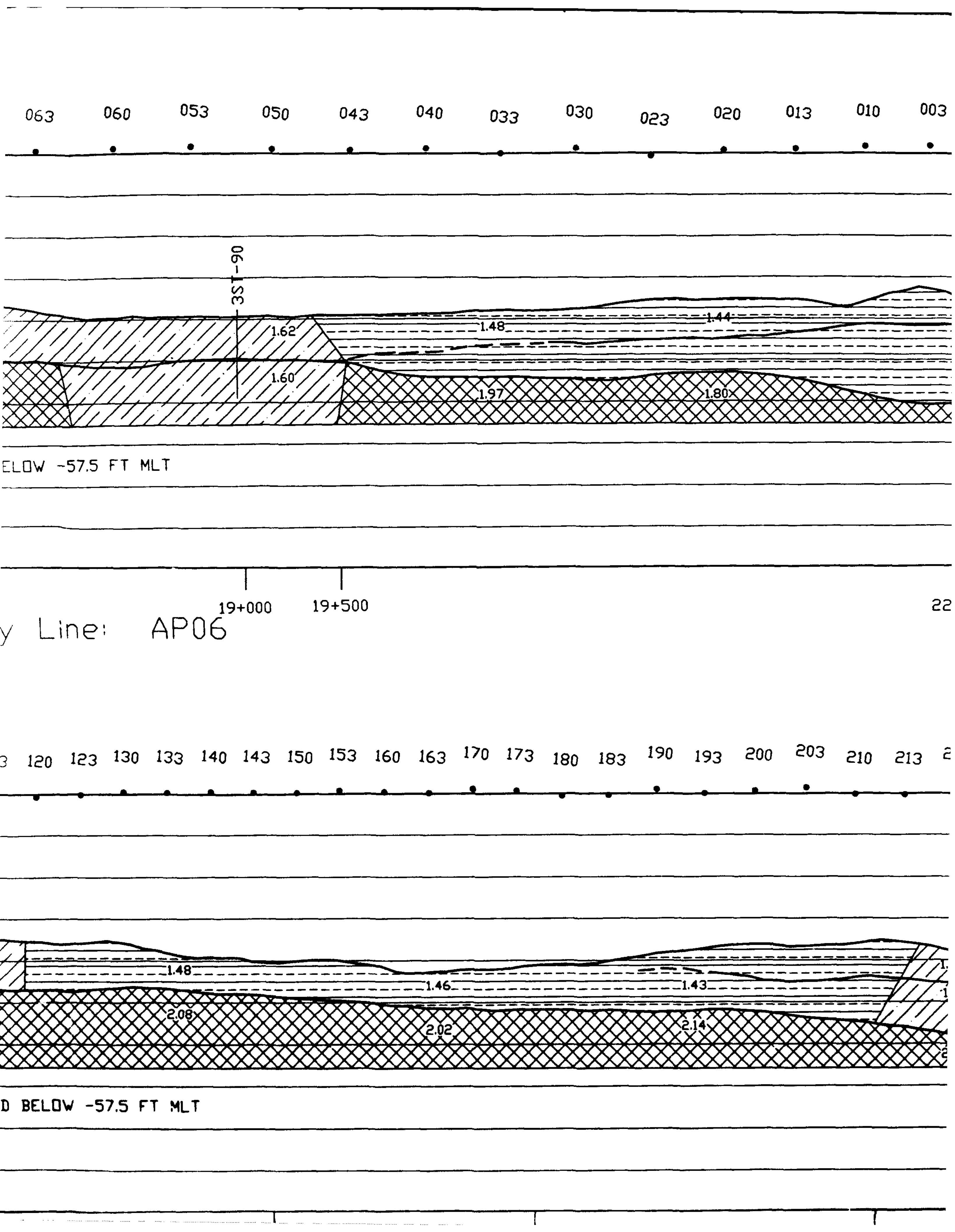
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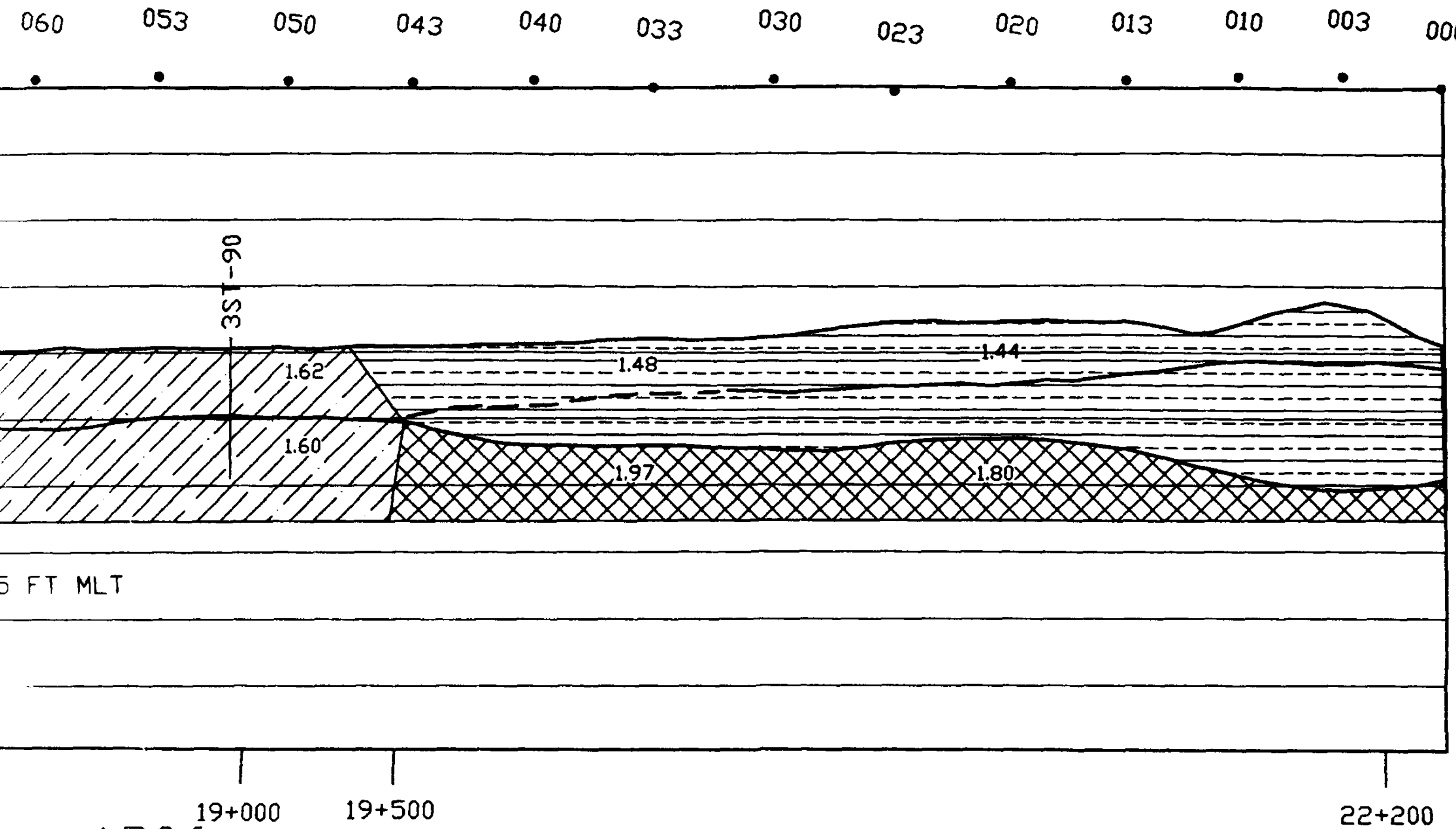
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5 FT MLT
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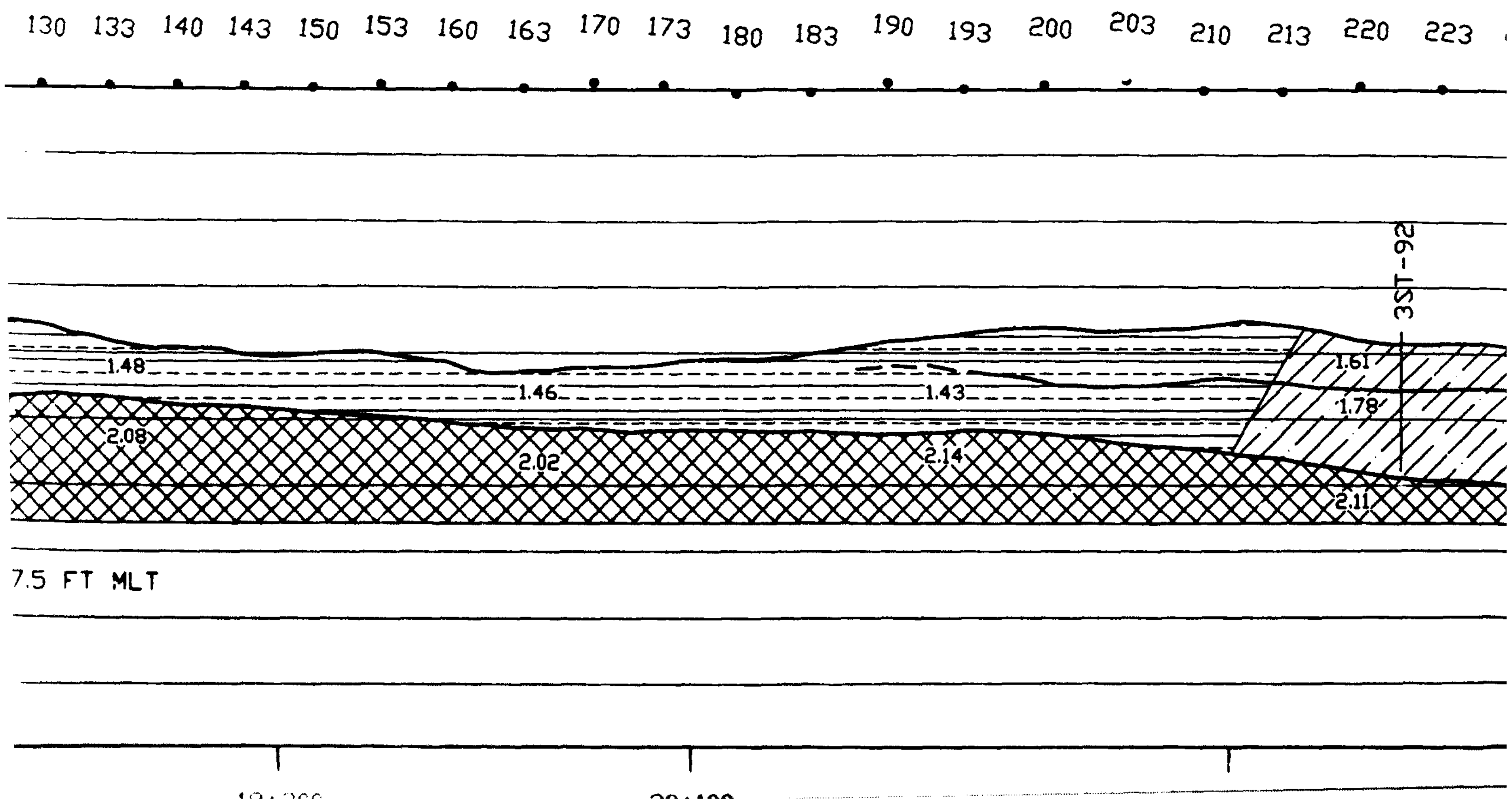
AP06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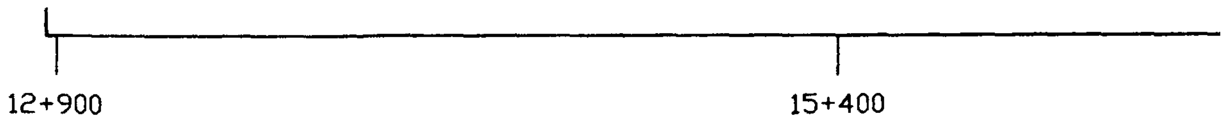
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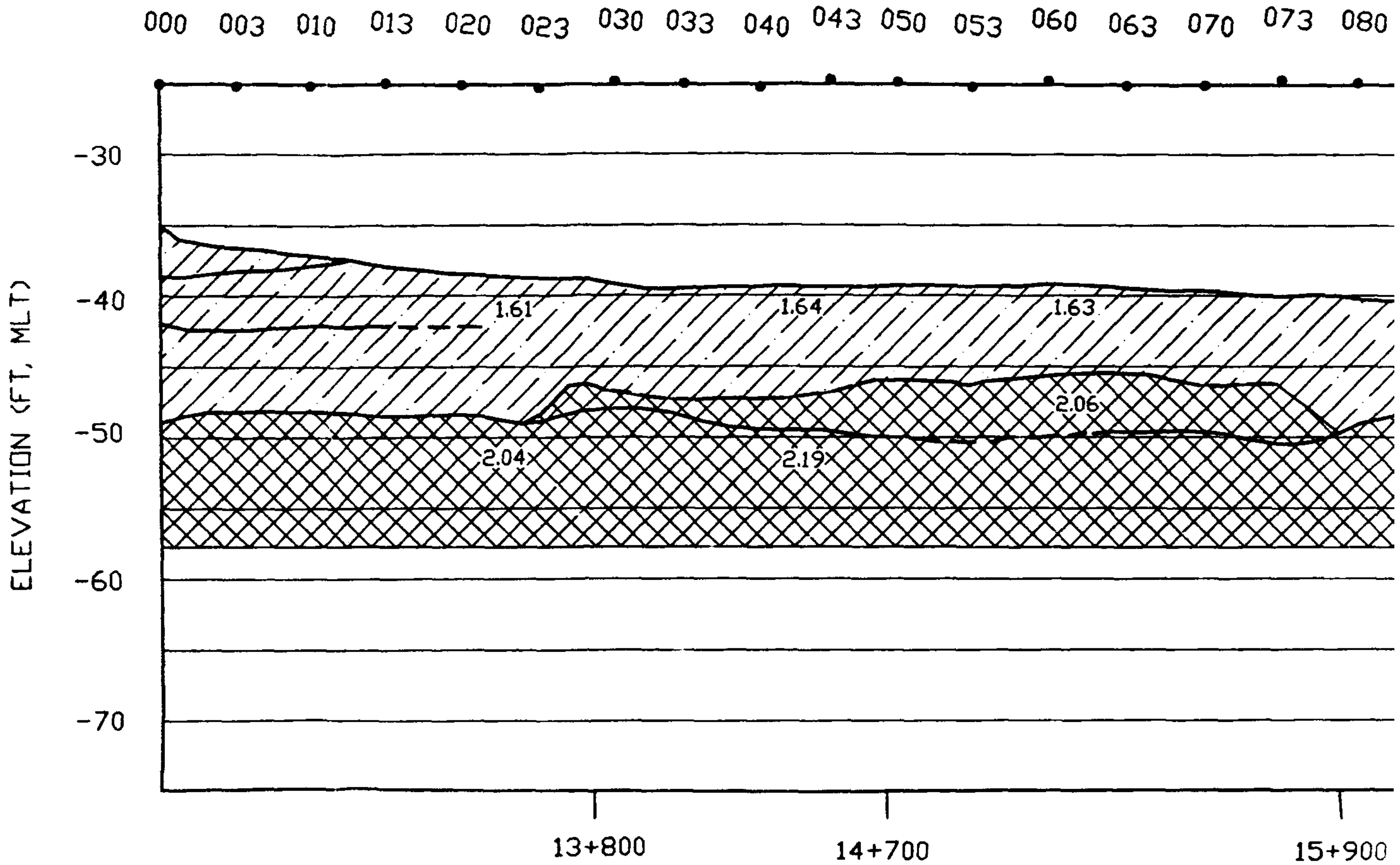
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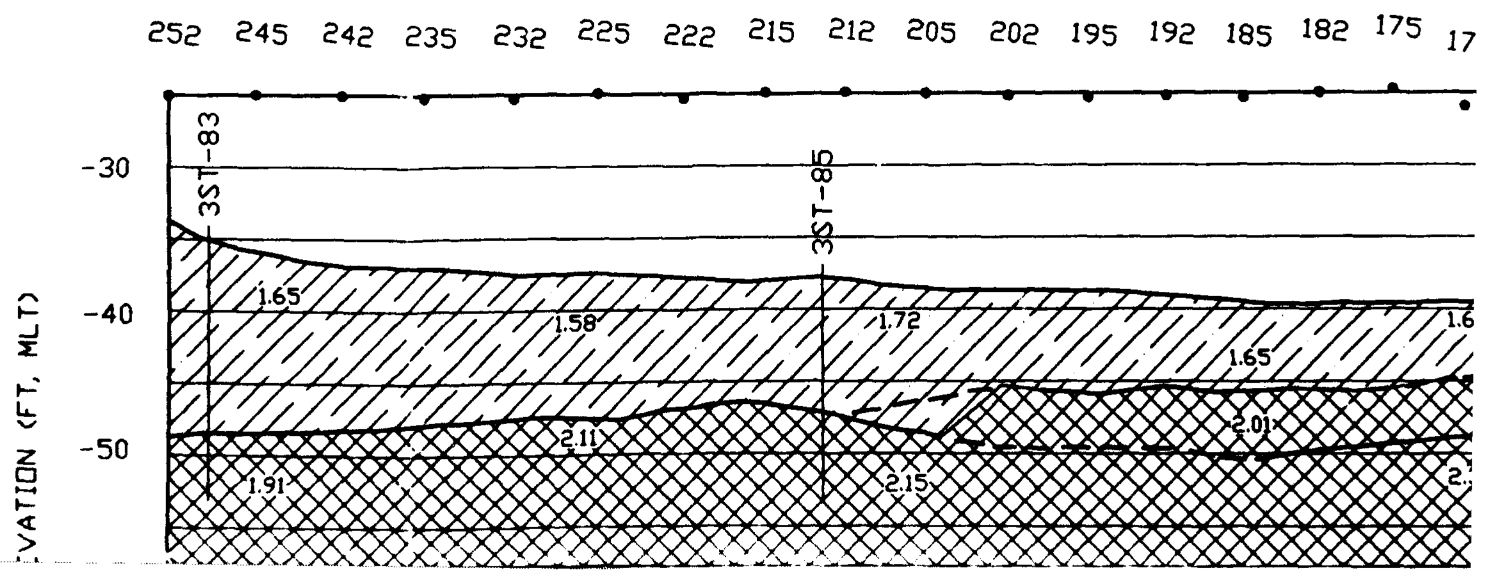
15+900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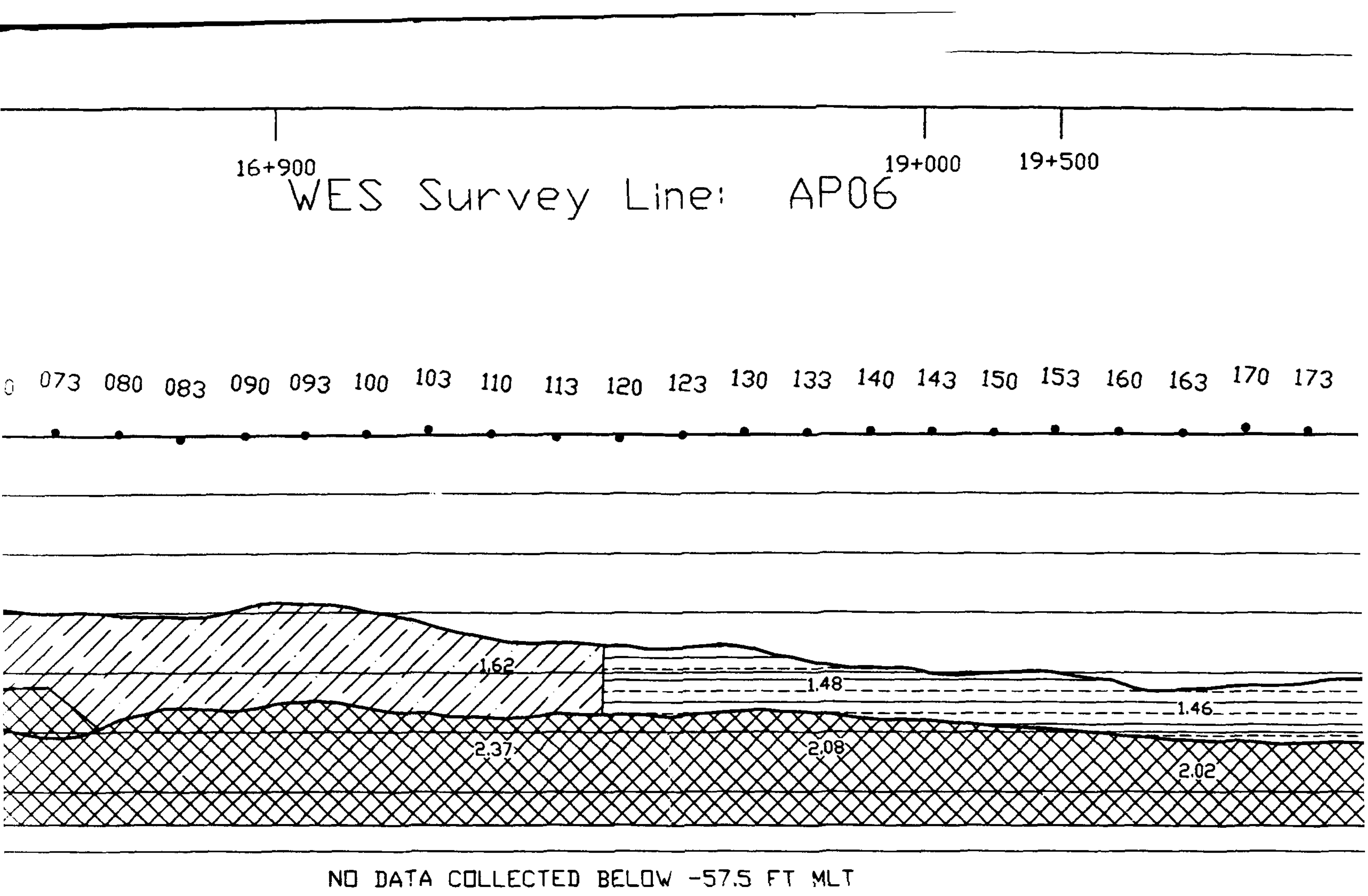
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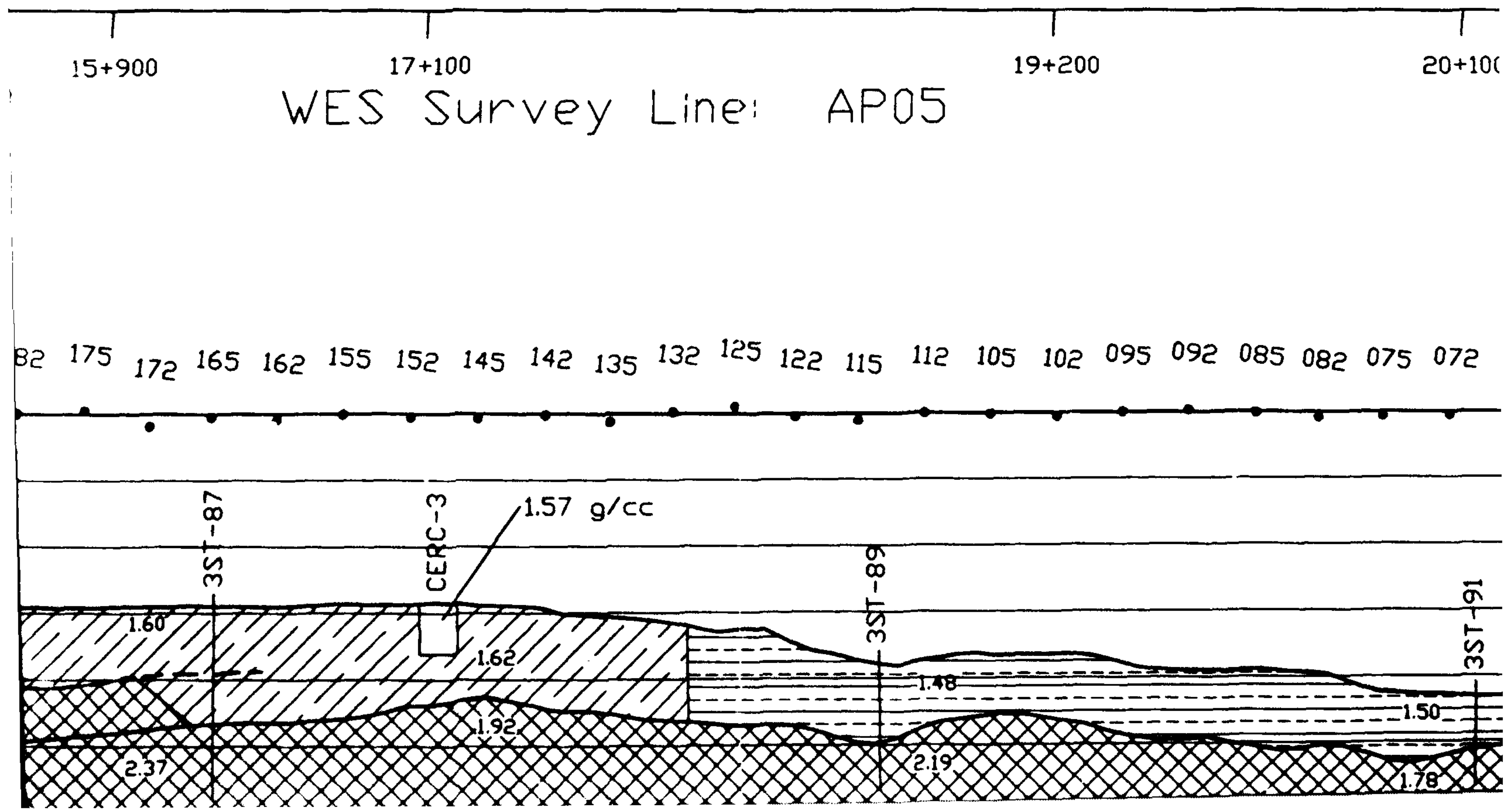
15+900
17+100
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20+100
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1.48
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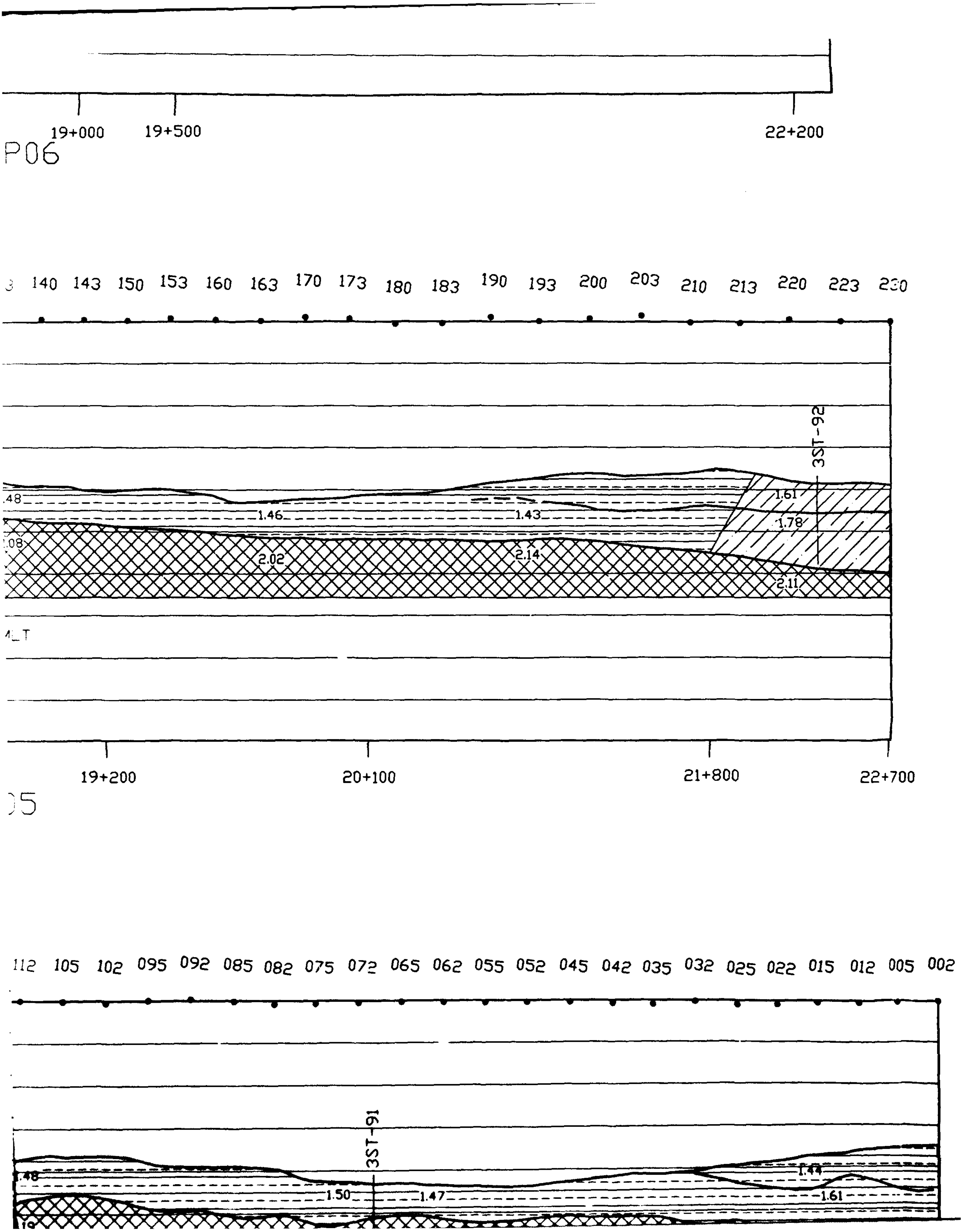
1.92
2.37
2.19
1.78


19+000
19+500
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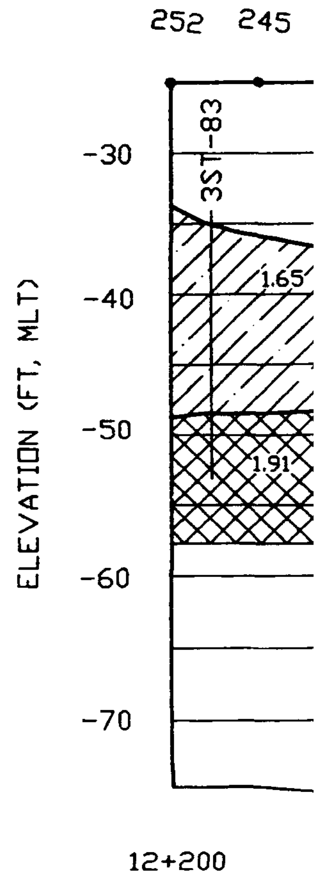
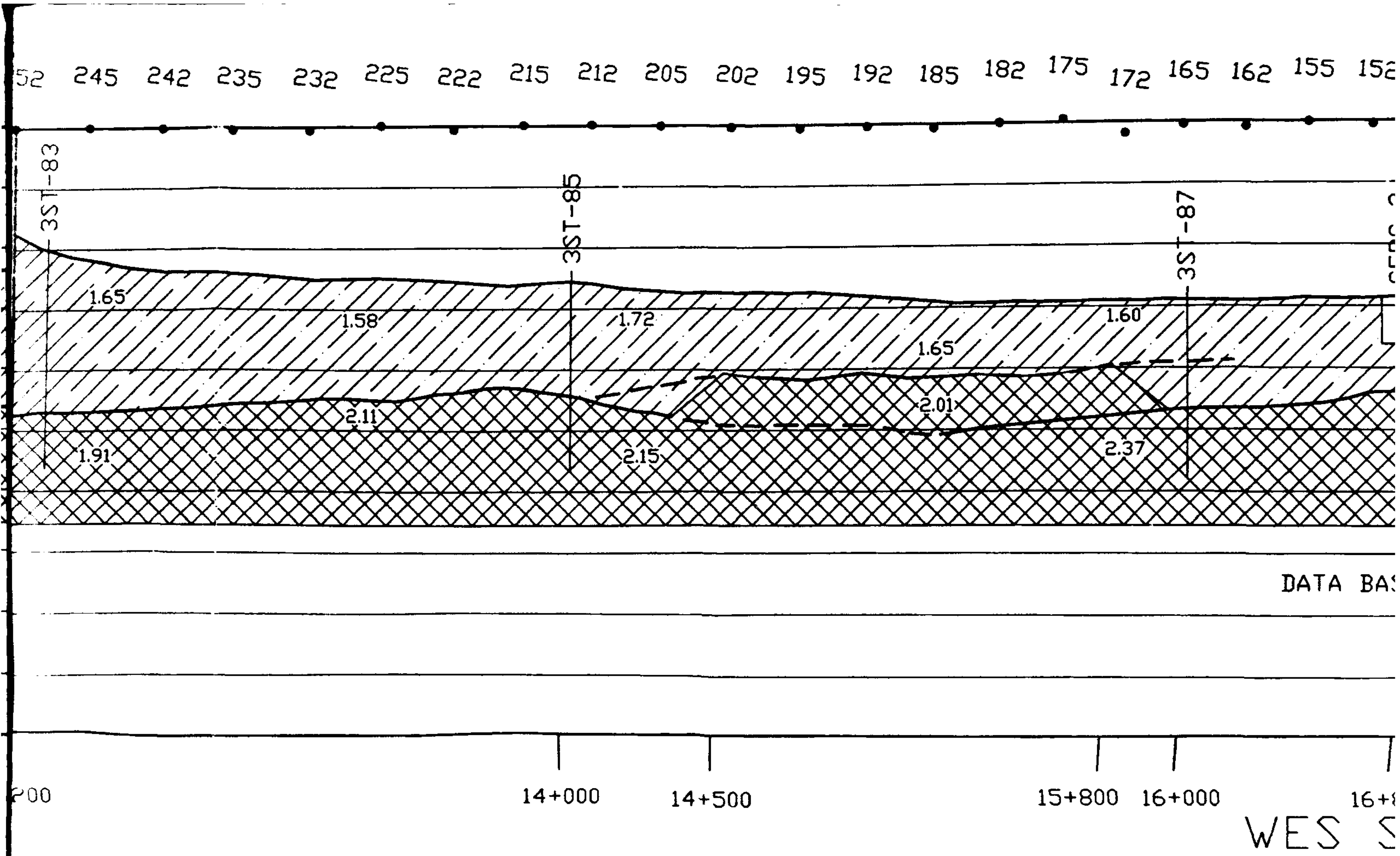


DENSITY RANGES (g/cm^3)

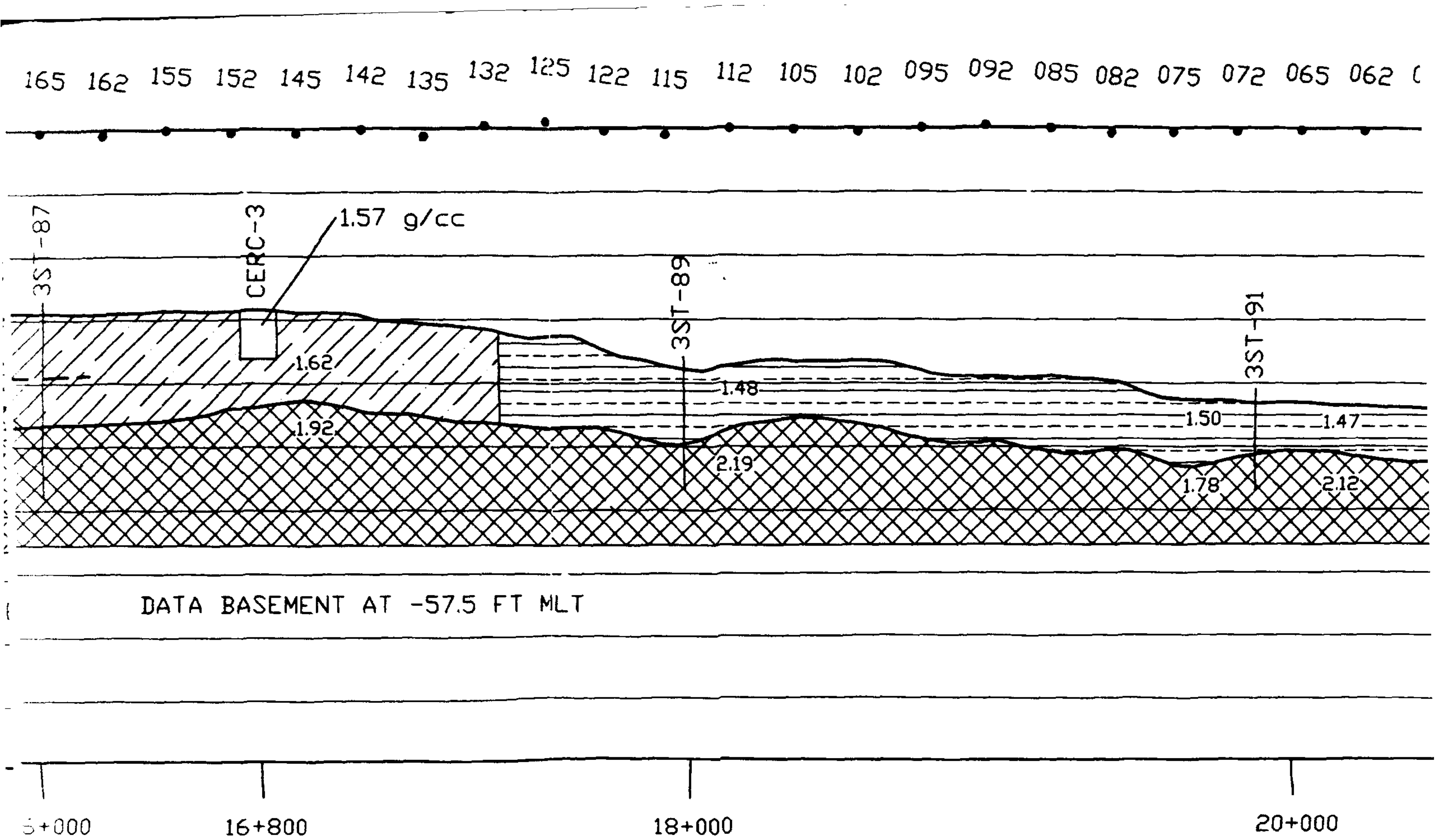
(diagonal hatch)	1.0 - 1.4
(horizontal dashed lines)	1.4 - 1.6
(broken diagonal hatch)	1.6 - 1.8
(blank)	1.8 - 2.3 *
(cross hatch)	1.8 - 2.3 #



NOTES

* Using CESWG Core In
densities are indicat
sandy material.

Using CESWG Core In
densities are indicat
moderate to stiff



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Core Information,
indicative of
stiff clays.

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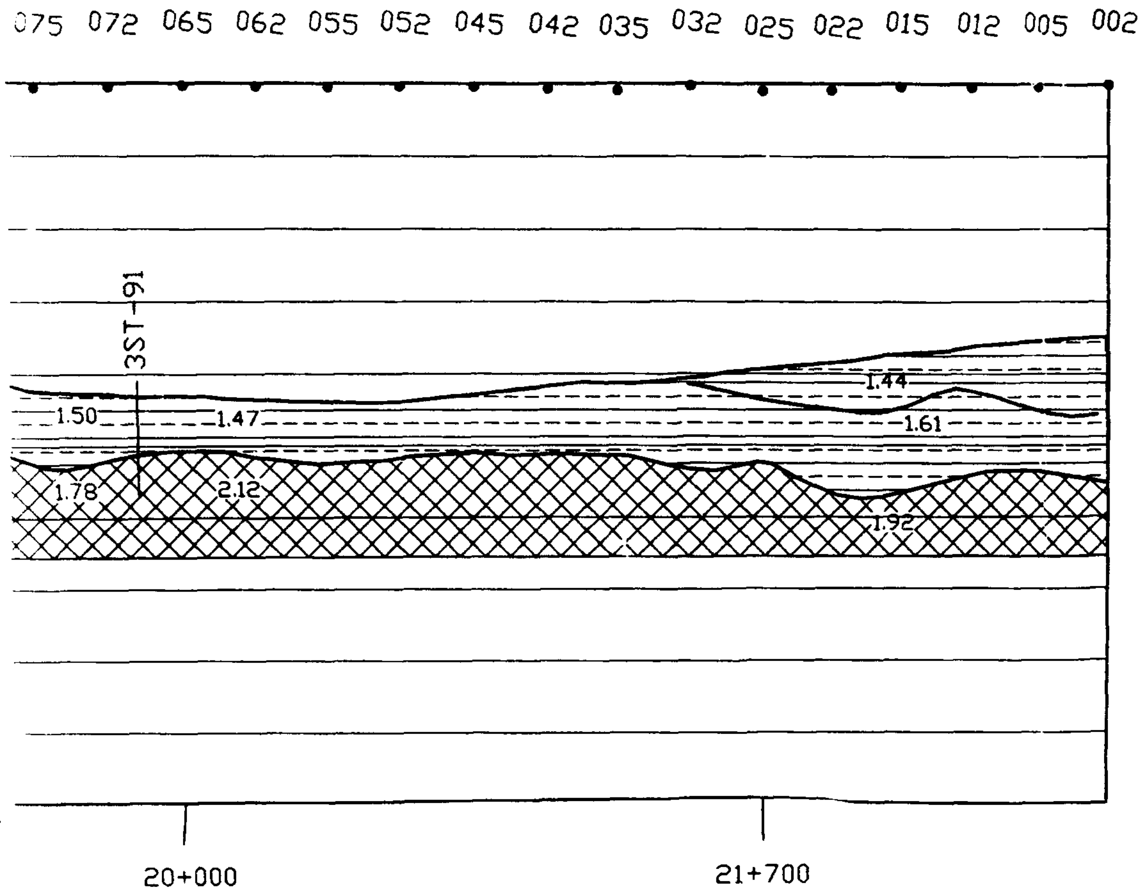
VERTICAL E



HORIZONTAL SCALE, FT

0 500 1000 2000

RTICAL EXAGGERATION = x 40

DESIGNED KJS
DRAWN BY: JMV
CHECKED KJS
SUPERVISE
SH.REF.NO.

DESIGNED BY: KJS	WATERWAYS EXPERIMENT STATION CORPS OF ENGINEERS VICKSBURG MS		
DRAWN BY: JMV			
CHECKED BY: KJS	ANCHORAGE BASIN GALVESTON, TEXAS		
SUPERVISED BY:			
SH.REF.NO.	SPEC.NO.	SIZE	FILE NO. PLATE 4 DRAWING NO.
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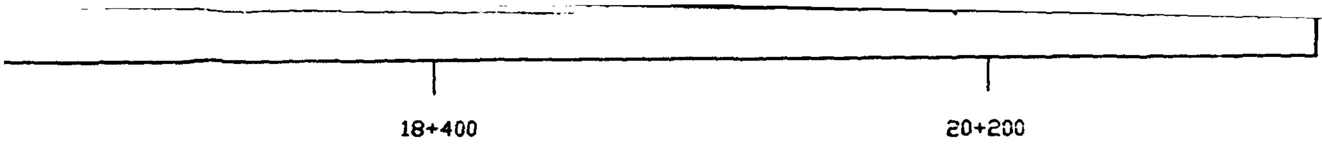
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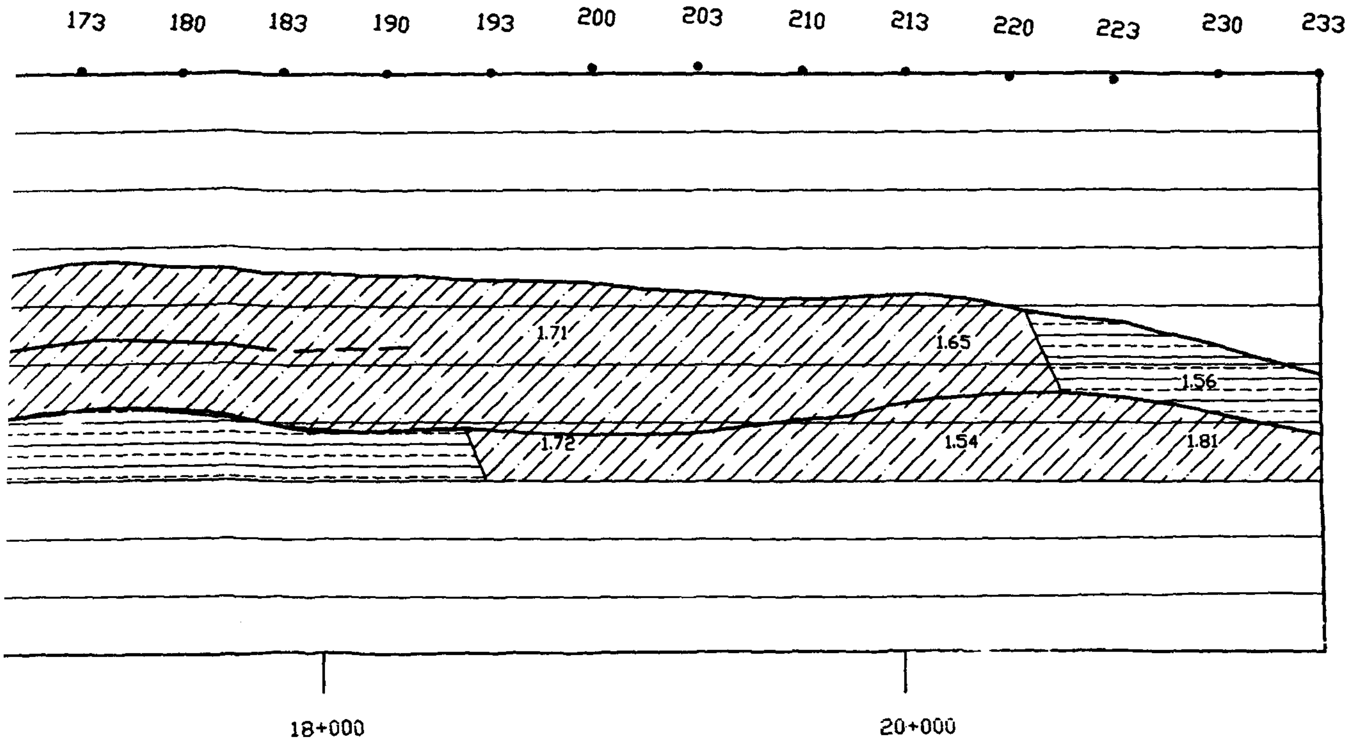
20+200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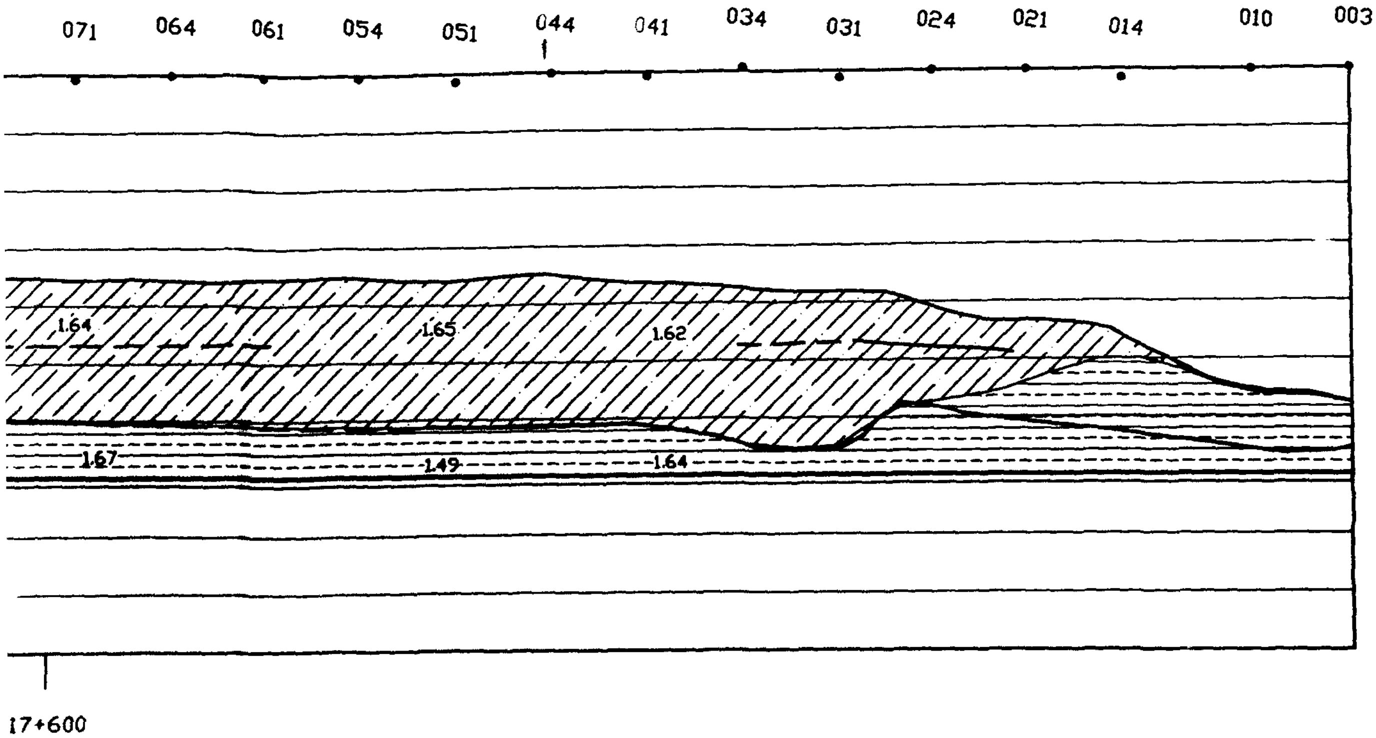
1.54
1.81
18+000
20+000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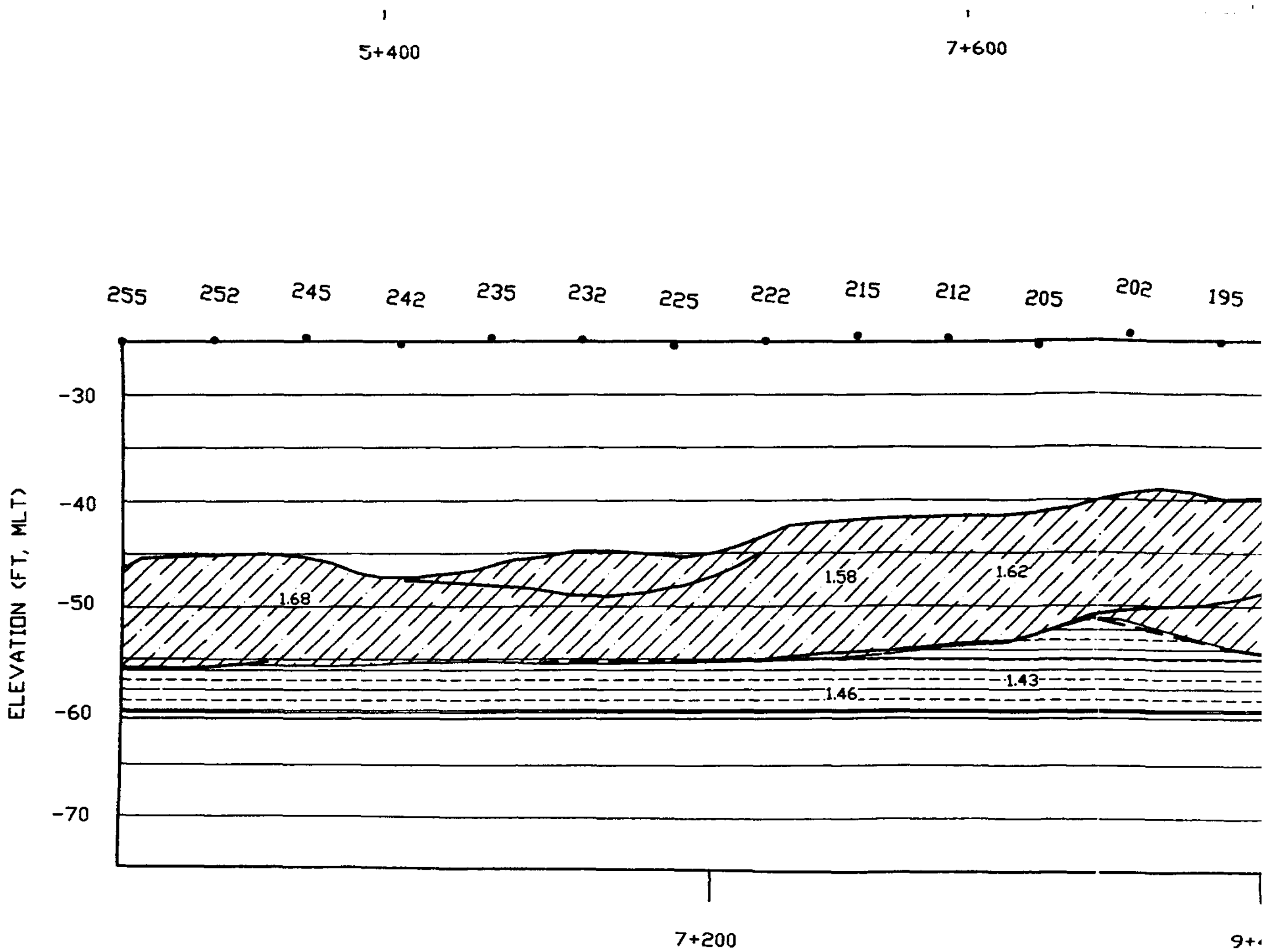
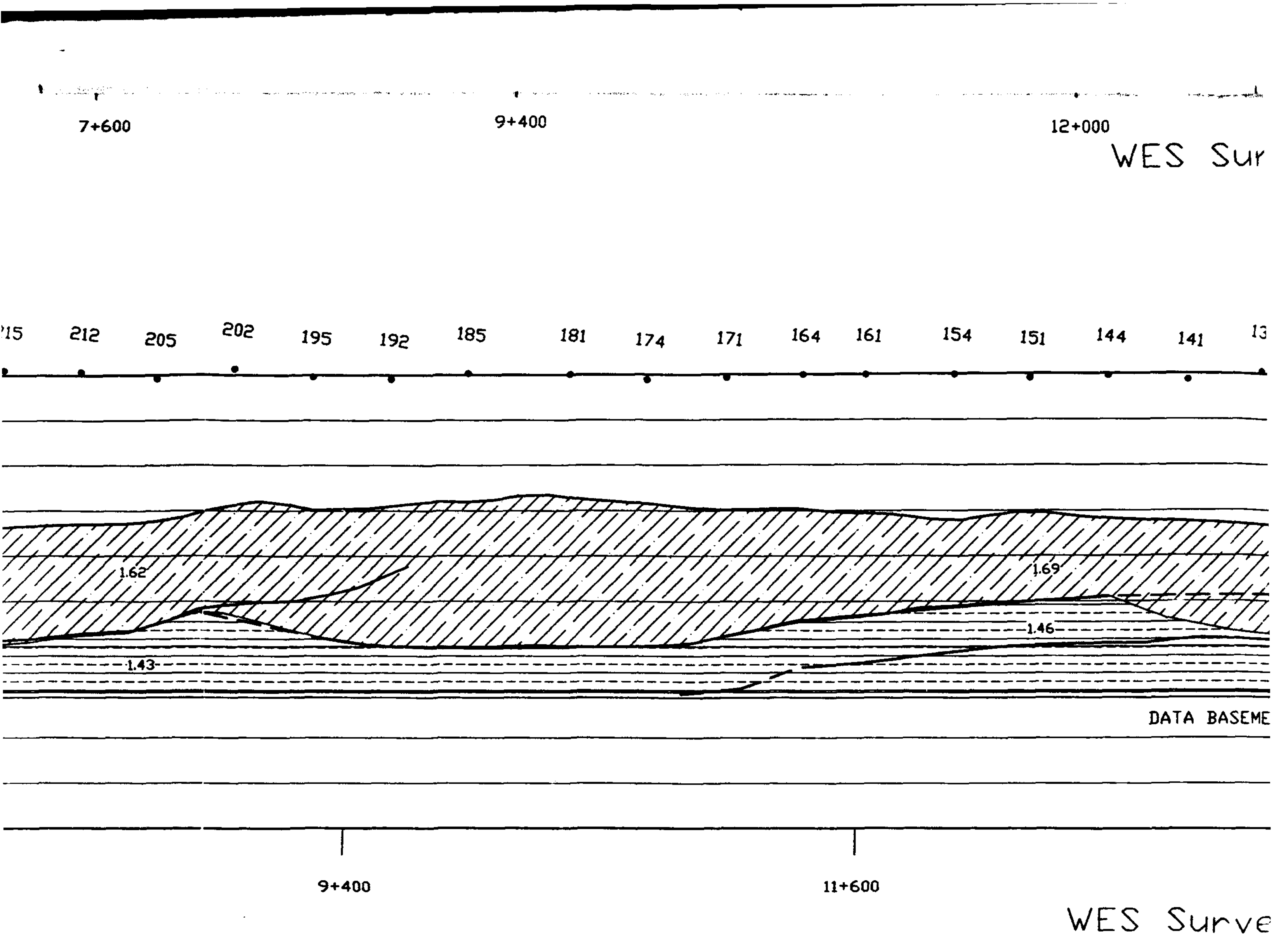
1.49
1.64
17+600



DENSITY RANGES (g/cm³)

	1.0 - 1.4
	1.4 - 1.6
	1.6 - 1.8
	1.8 - 2.3 *
	1.8 - 2.3 #



3)

NOTES

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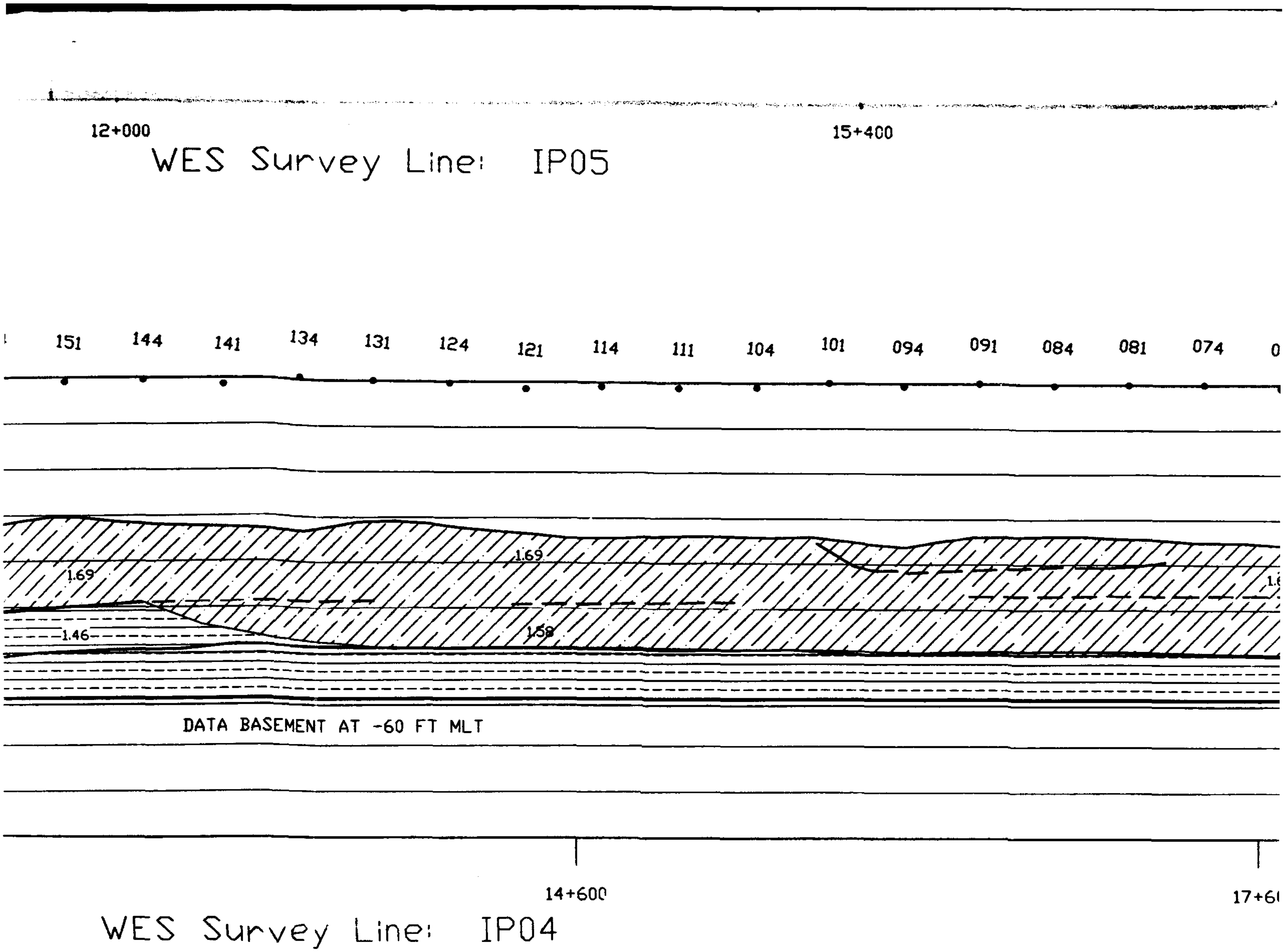
sandy material.

\# Using CESWG Core Informati
densities are indicative of
moderate to stiff clays.



HORIZONTAL SCALE

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VERTICAL EXAGGERATION

re Information,
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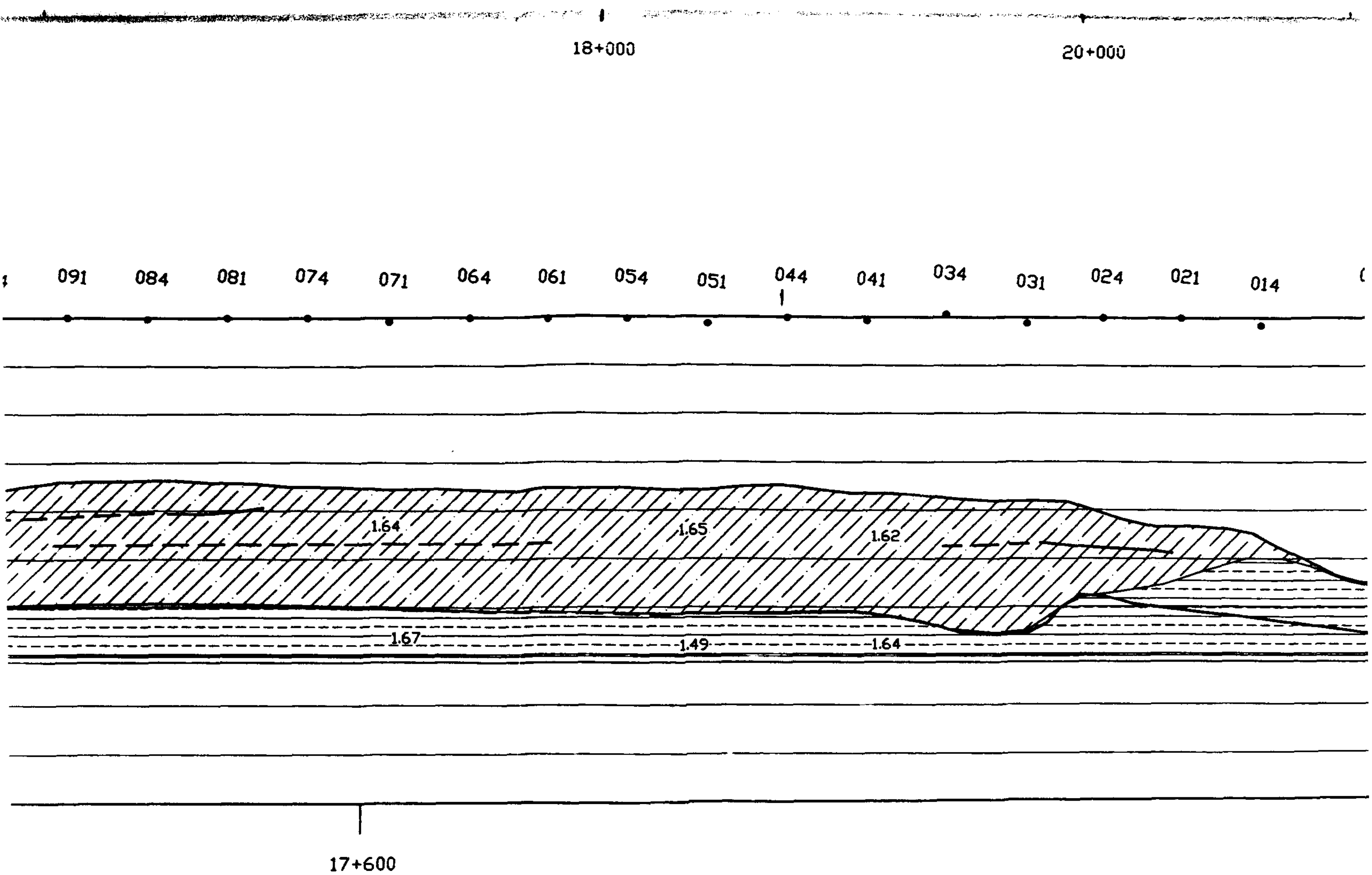
tiff clays.



INTAL SCALE, FT

500 1000 2000

EXAGGERATION = × 40

DESIGNED BY: KJS
DRAWN BY: JMV
CHECKED BY: KJS
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WATERWAYS EXPERIMENT S
CORPS OF ENGINEERS
VICKSBURG MS

INNER BAR CHA
GALVESTON, TE

SH.REF.NO.
SPEC.NO.
SIZE
FILE NO.
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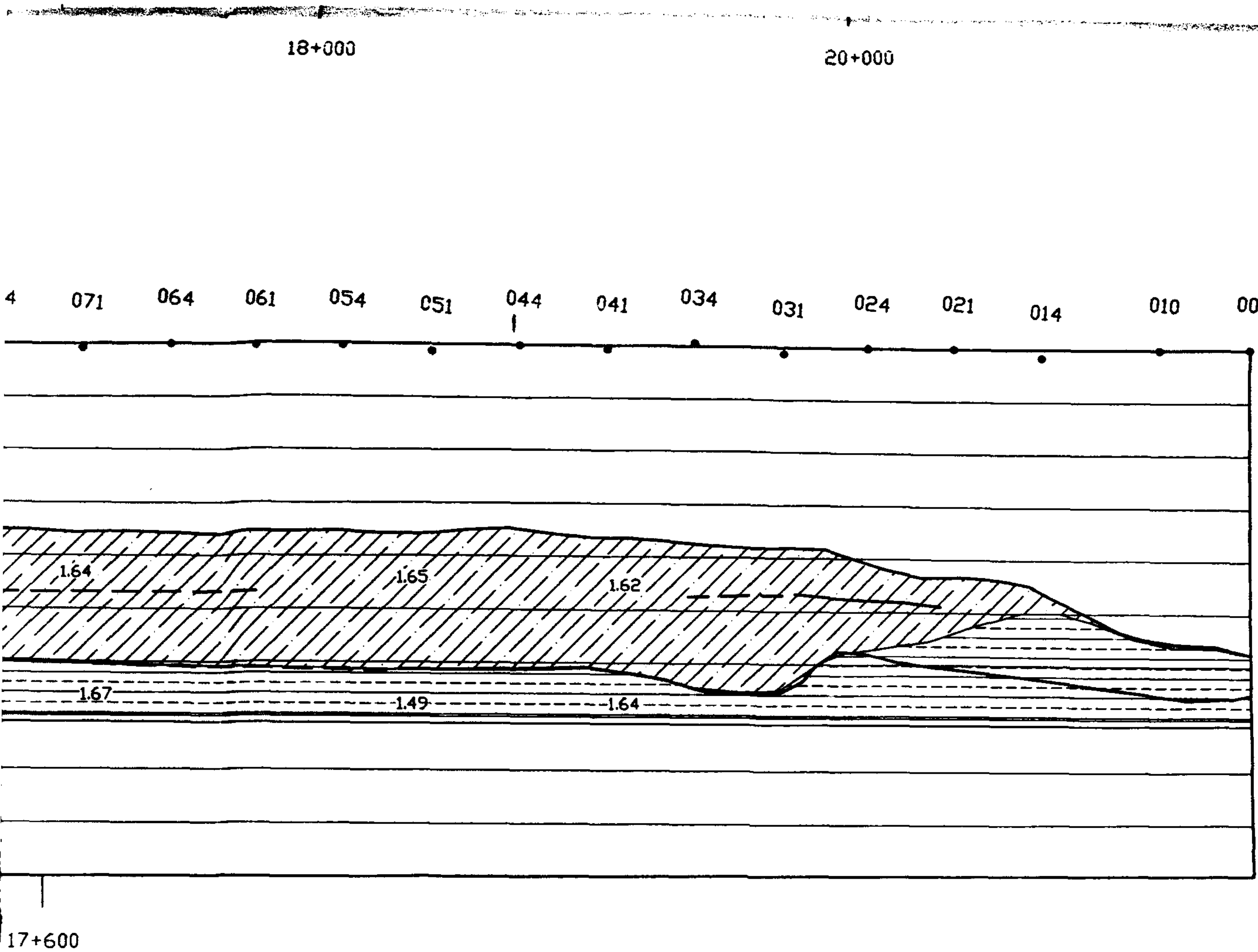
SCALE: 1=600
DATE: 7 JUNE 1993



LE, FT

2000

ON = x 40

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DRAWN BY: JMV	INNER BAR CHANNEL GALVESTON, TEXAS		
CHECKED BY: KJS			
SUPERVISED BY:			
SH.REF.NO.	SPEC.NO.	SIZE	FILE NO. DRAWING NO. PLATE 2
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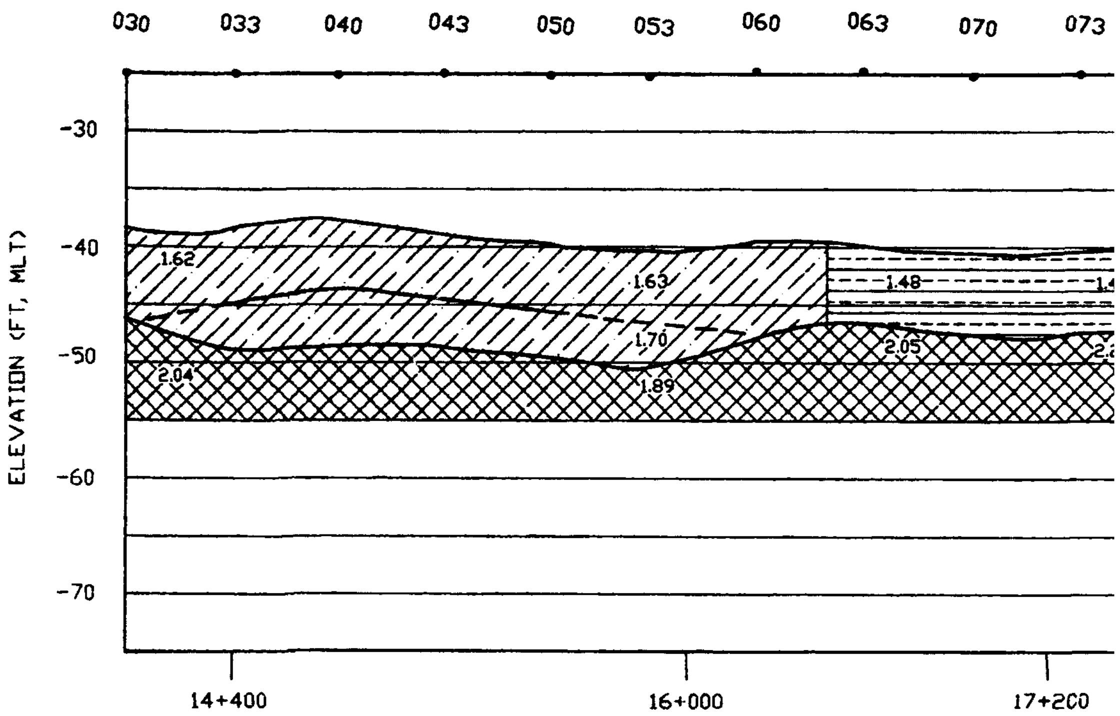
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-30
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-50
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-70
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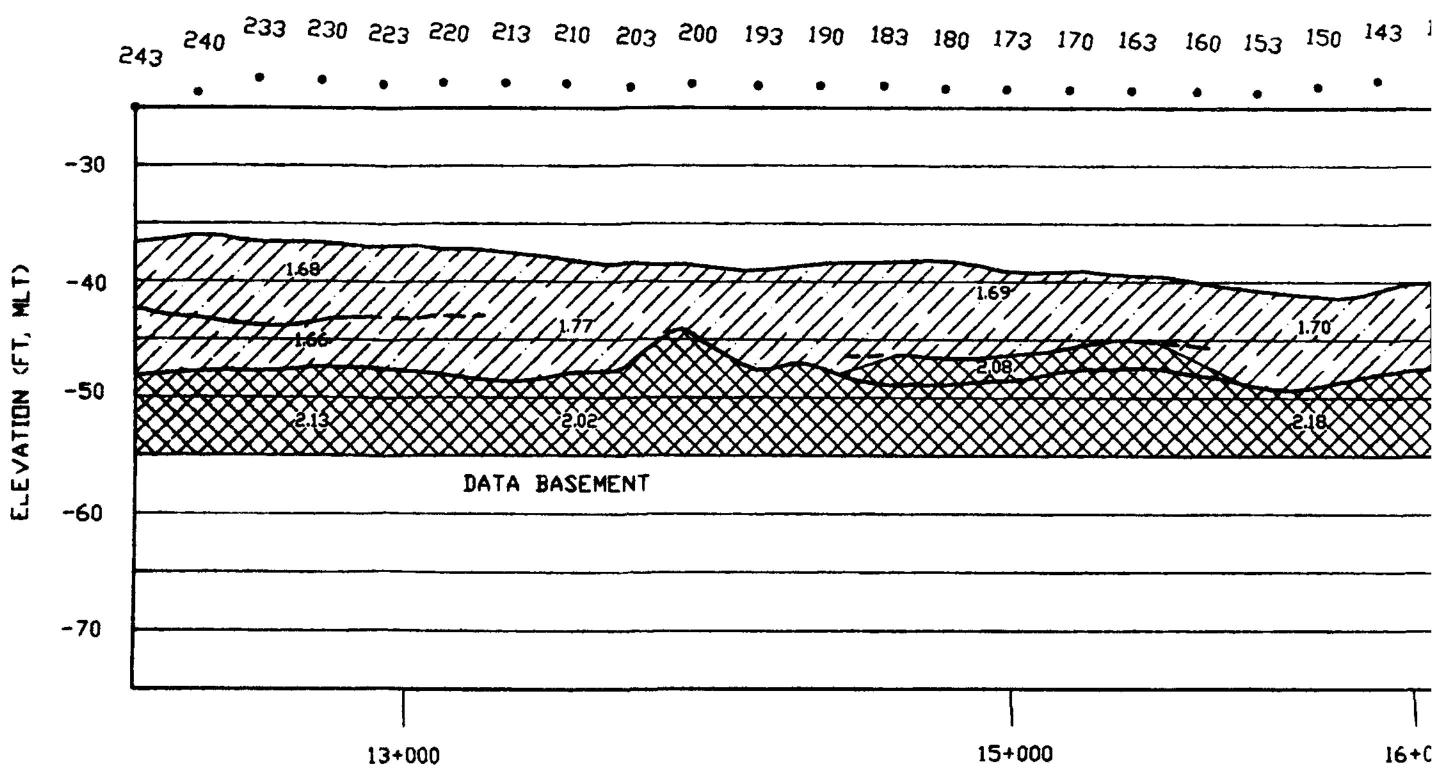
1.62
1.63
1.48
1.70
2.04
1.89
2.05
14+400
16+000
17+200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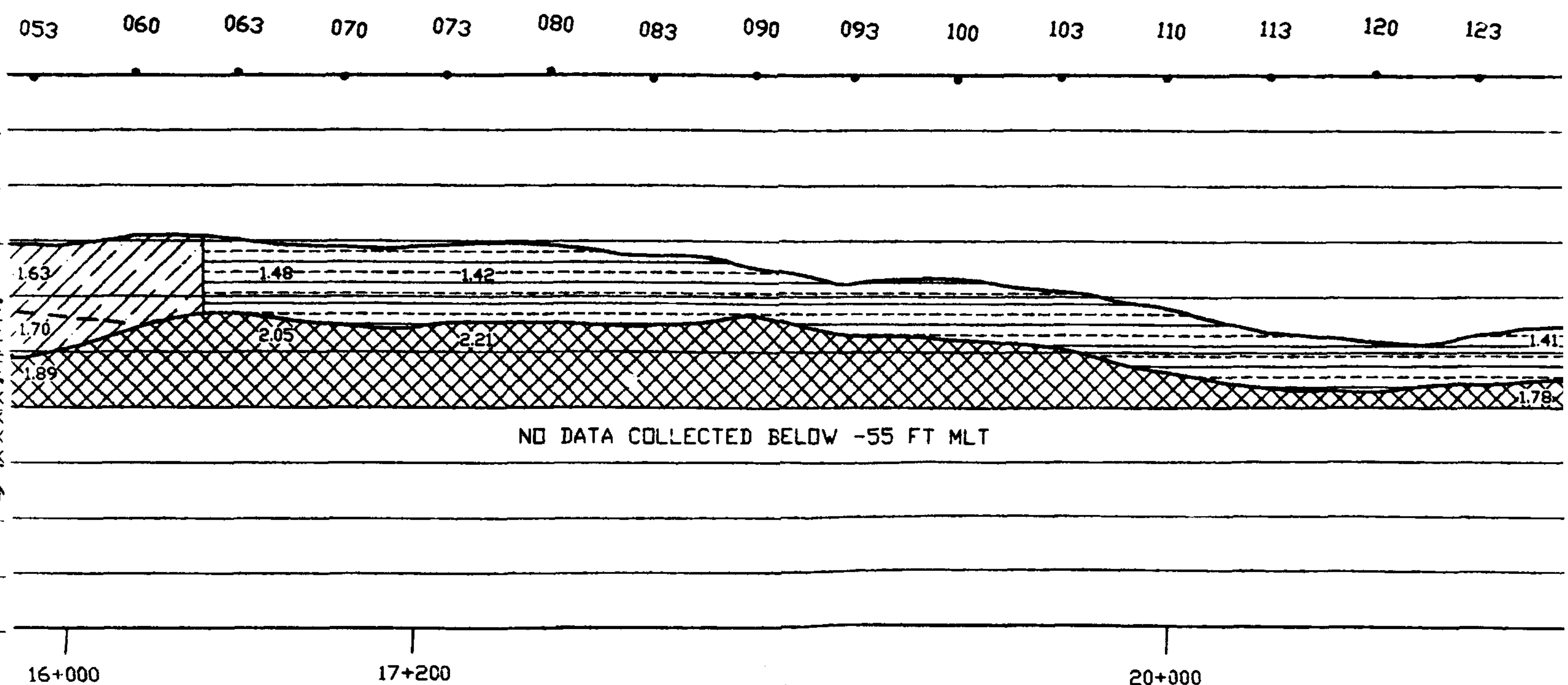
2.02
2.18
DATA BASEMENT
13+000
15+000



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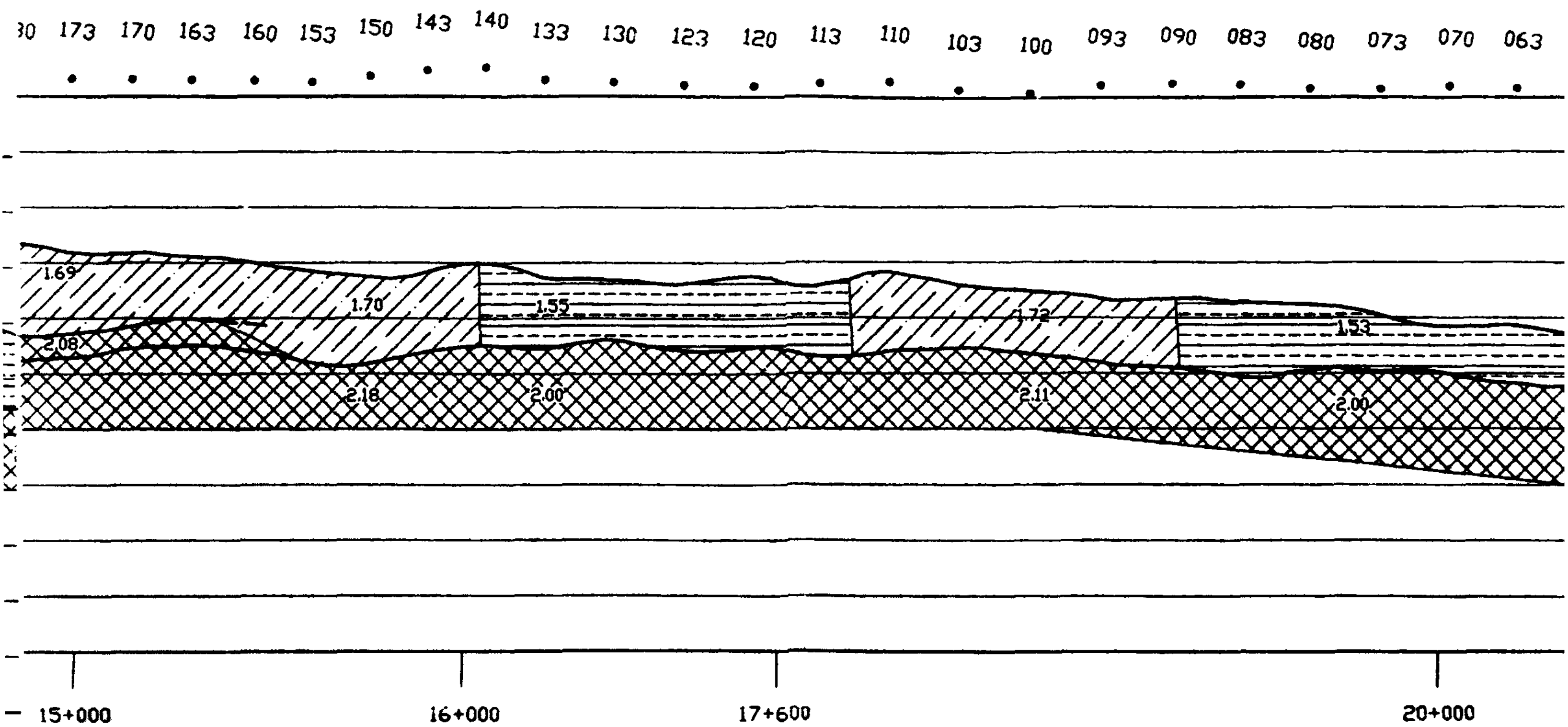

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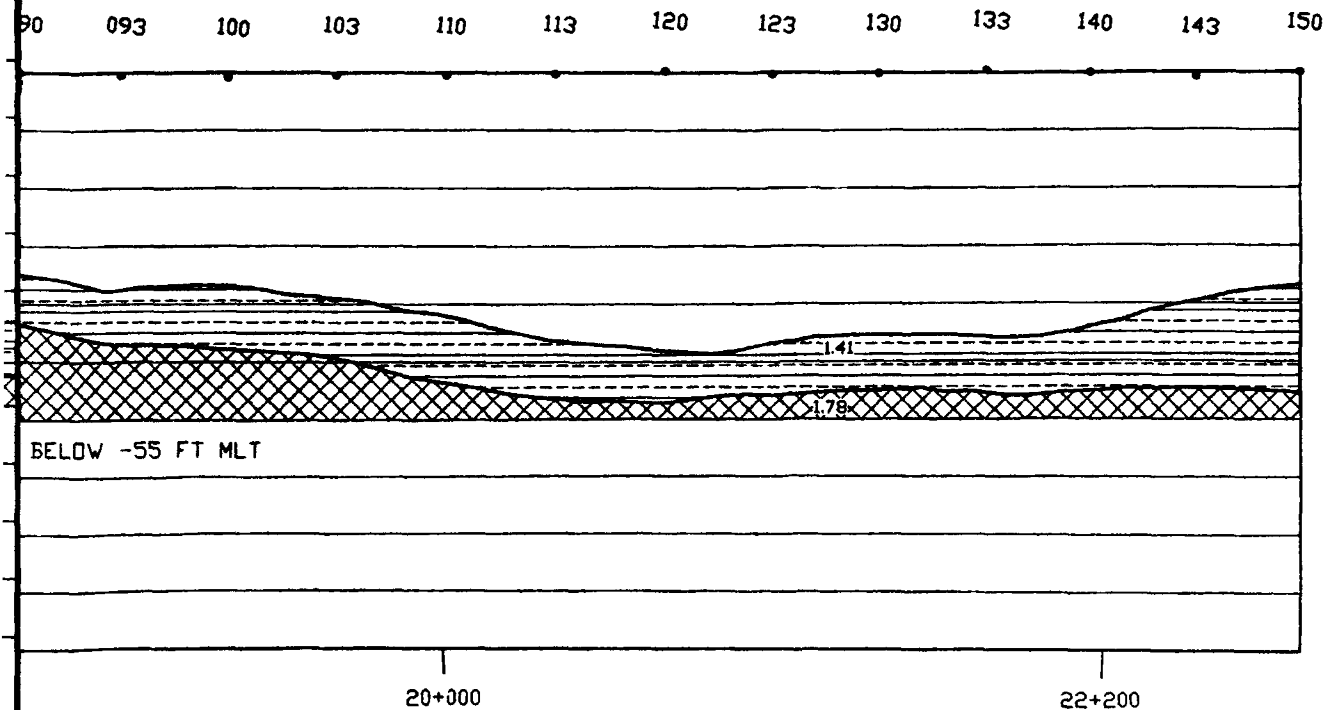

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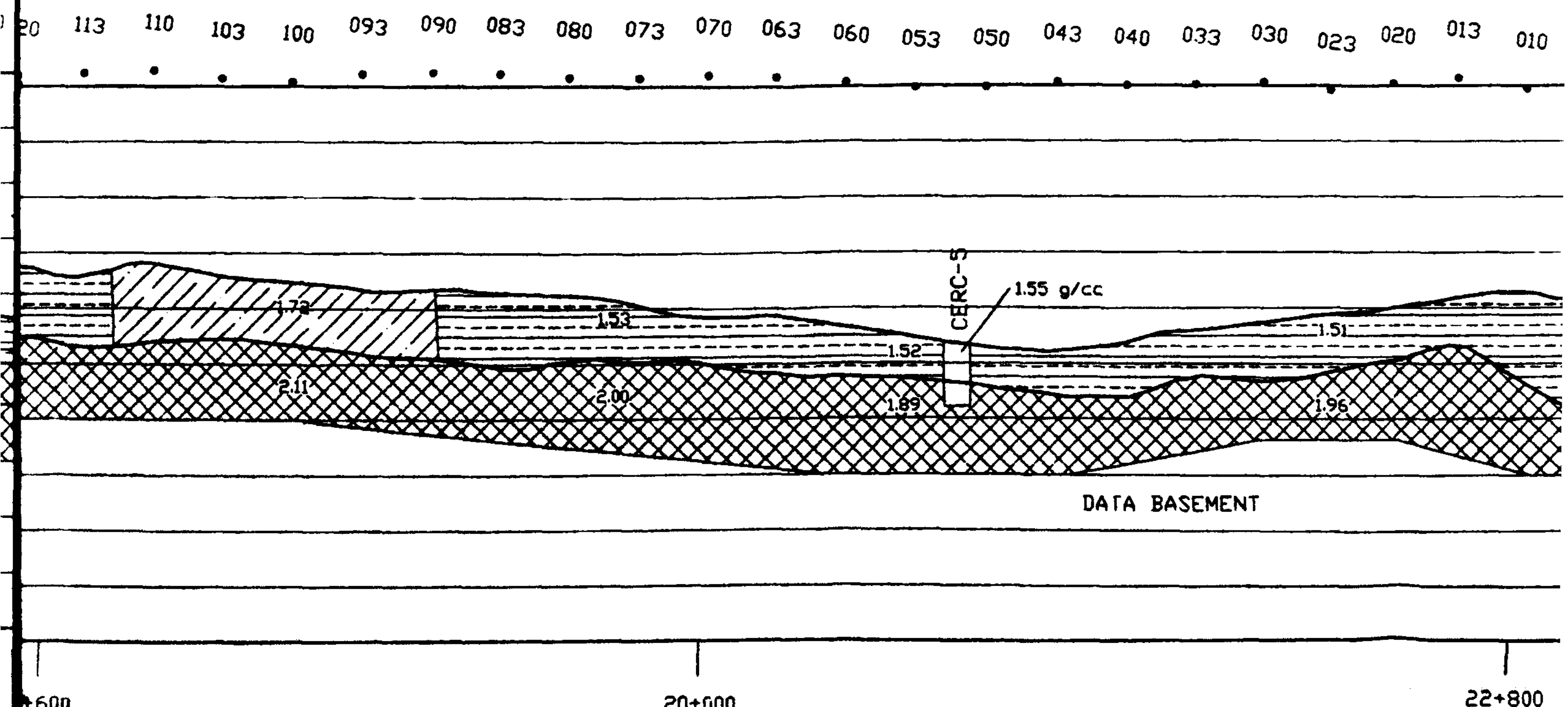

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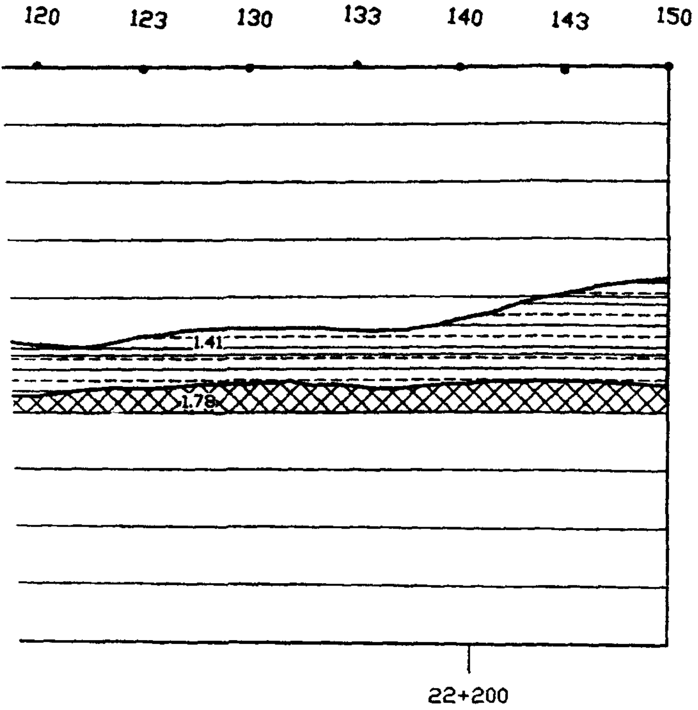

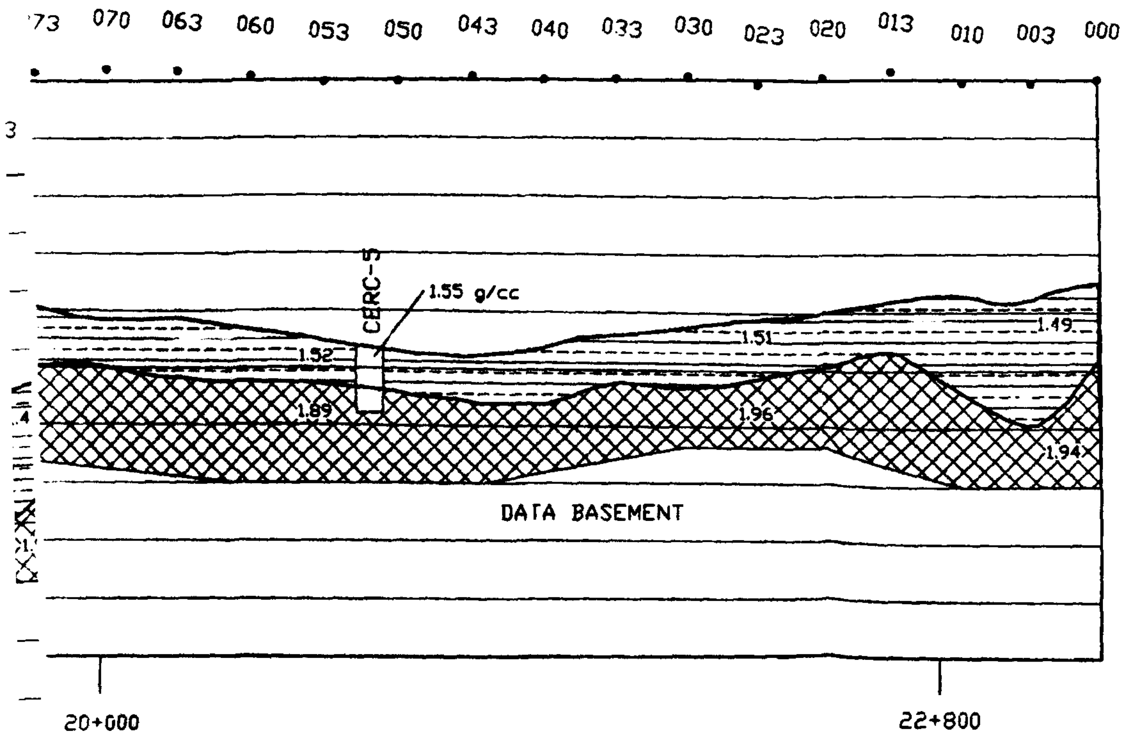

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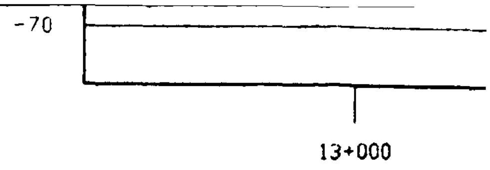
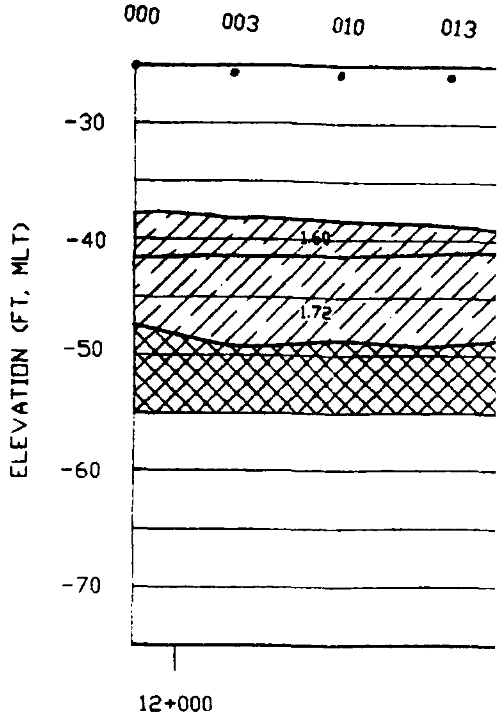




DENSITY RANGES (g/cm³)

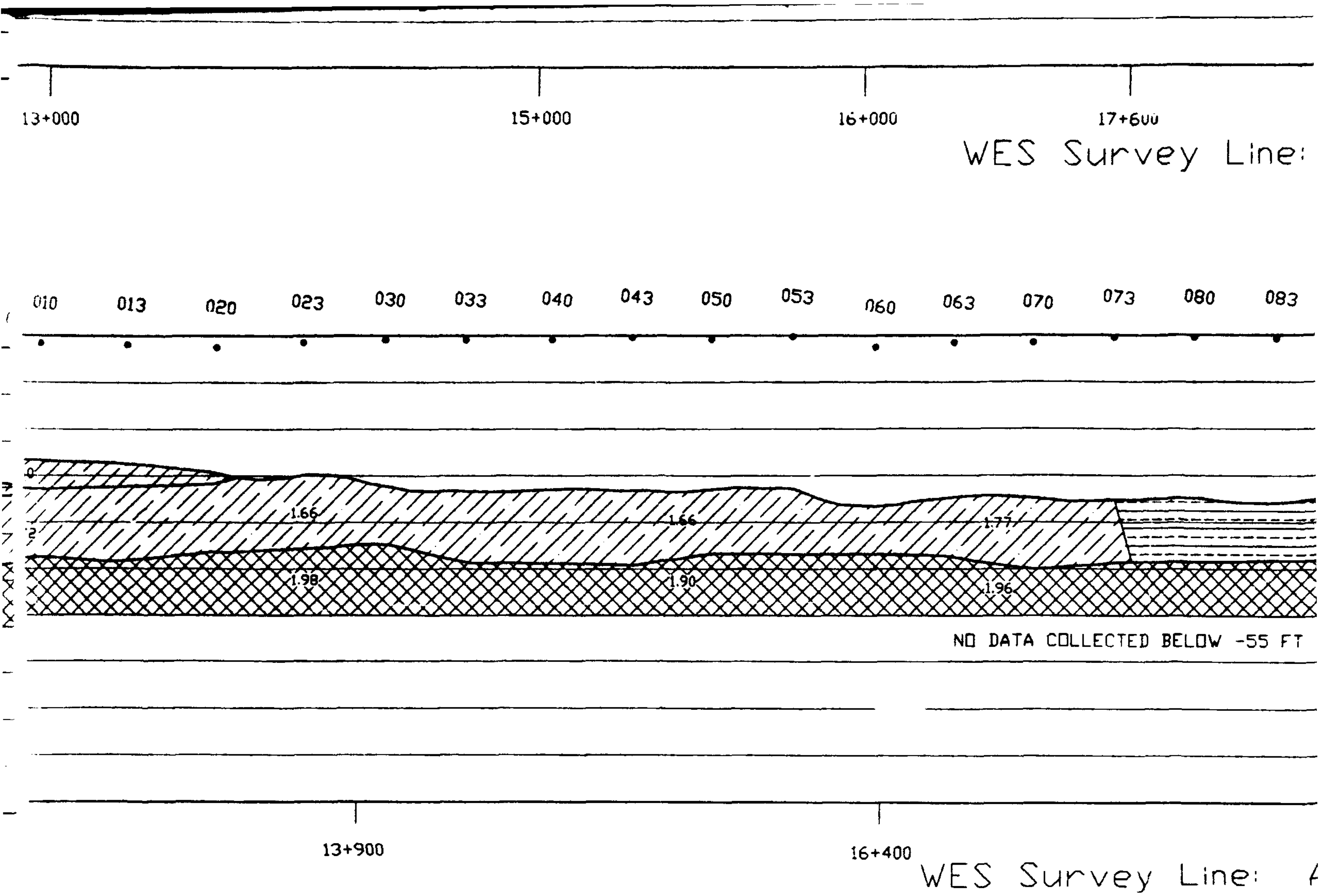
1.0 - 1.4

1.4 - 1.6

1.6 - 1.8

1.8 - 2.3 *

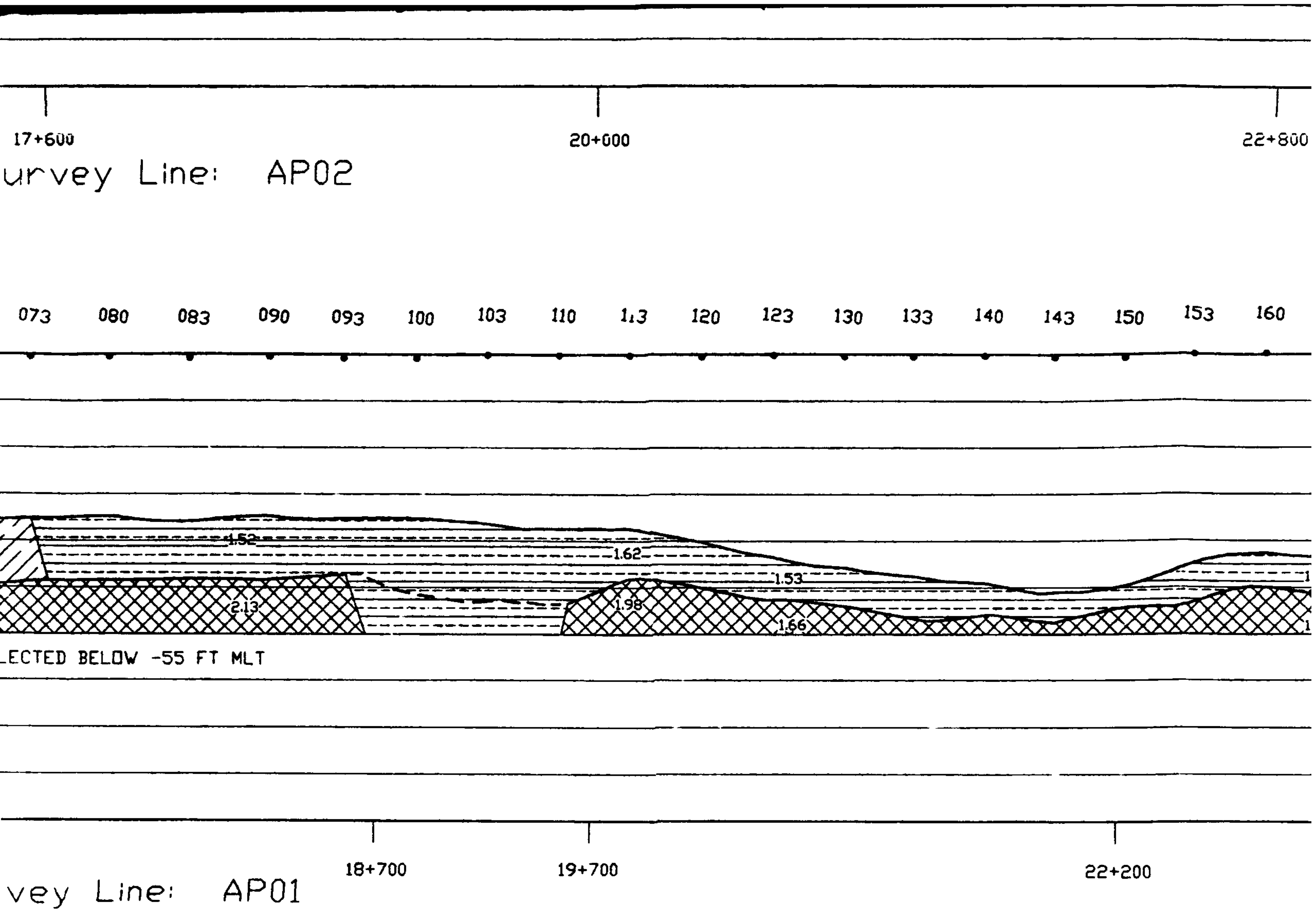
1.8 - 2.3 #



NOTES

* Using CESWG Core Information, densities are indicative of sandy material.

Using CESWG Core Information, densities are indicative of moderate to stiff clays.



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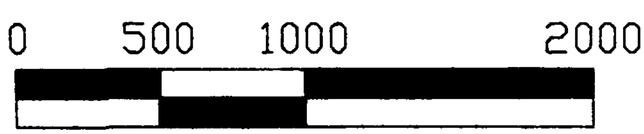

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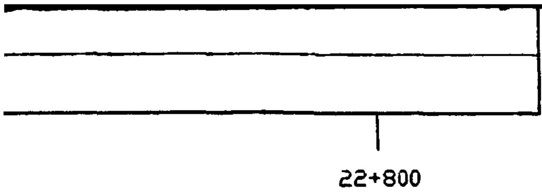
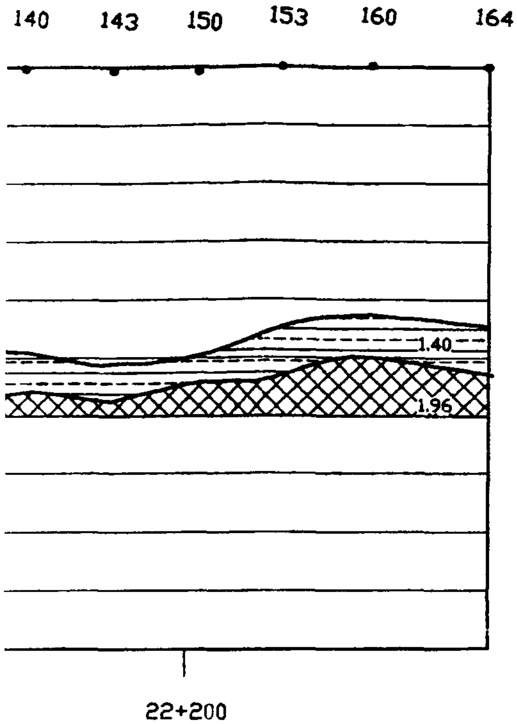
VERTICAL EXAGGERATION = x 40

.tion,





LE, FT

2000

ON = x 40

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DRAWN BY: JMV			
CHECKED BY: KJS	ANCHORAGE BASIN GALVESTON, TEXAS		
SUPERVISED BY:			
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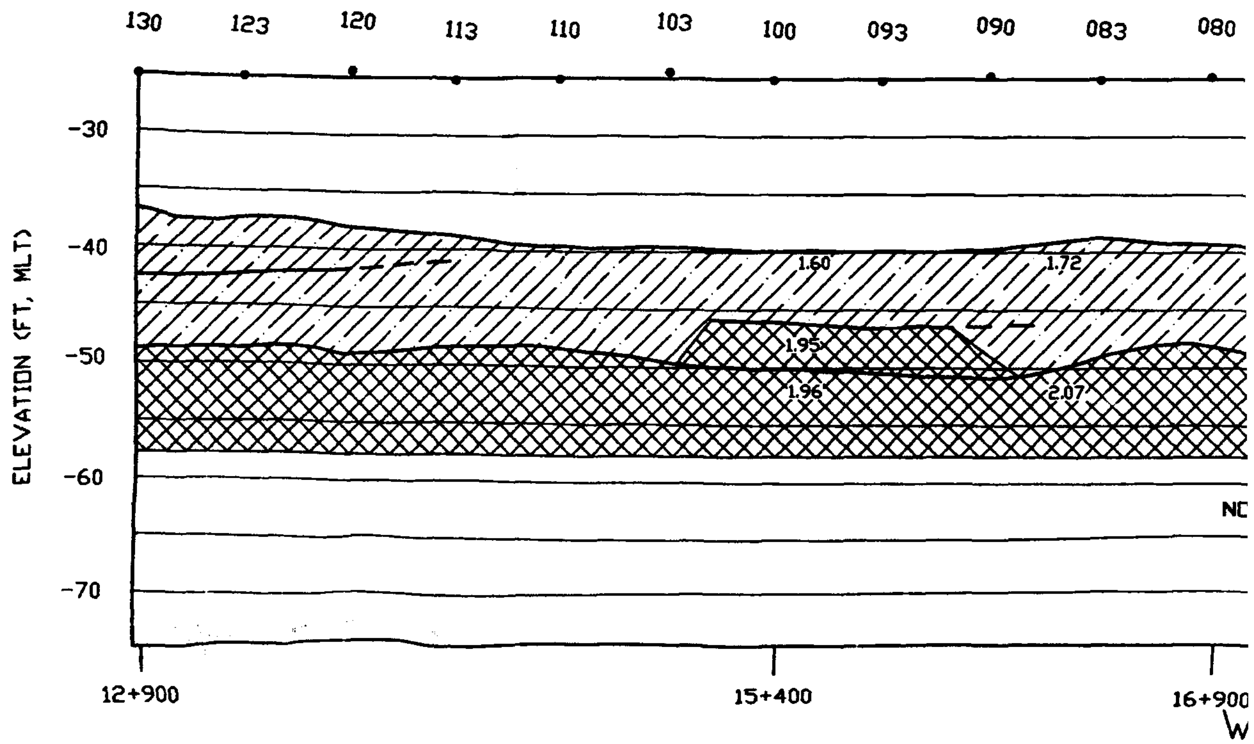
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1.72
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1.96
2.07
NC
12+900
15+400
16+900
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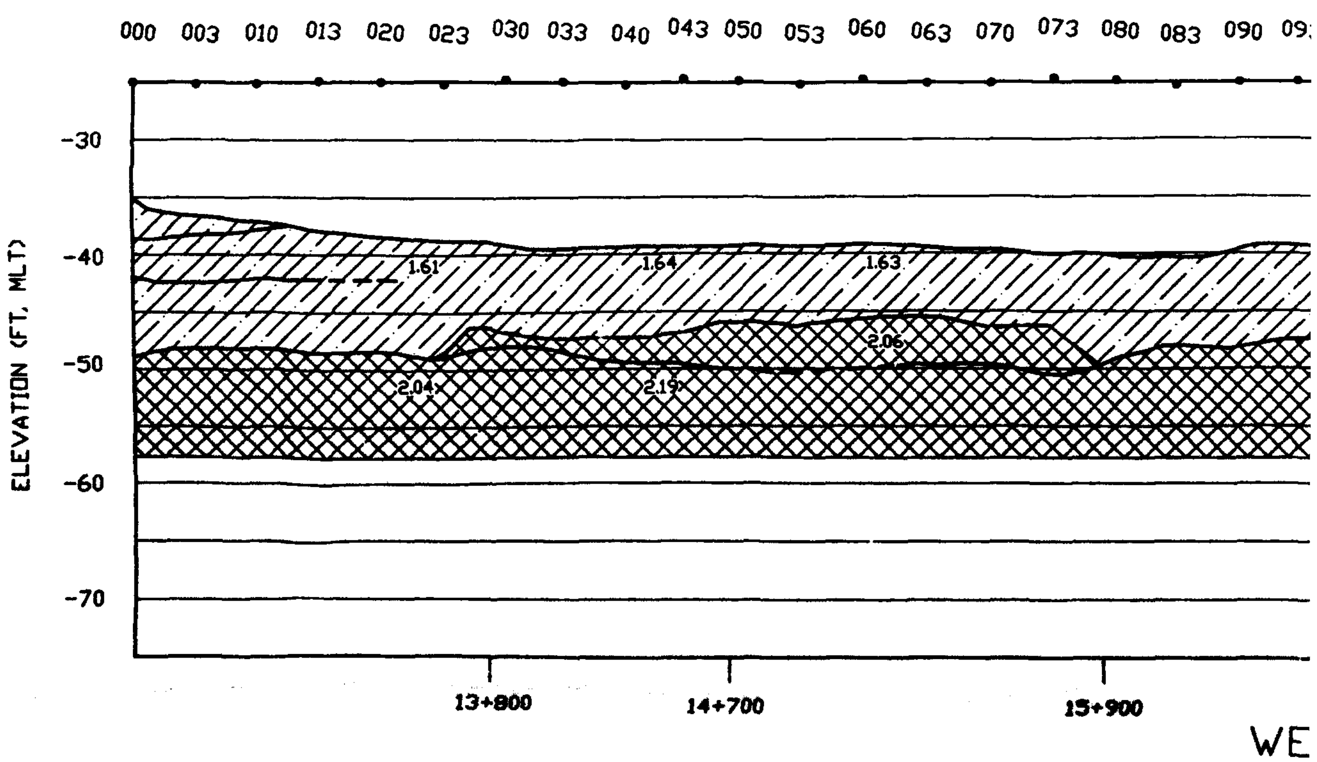
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-70
ELEVATION (FT, MLT)
1.61
1.64
1.63
2.06
2.04
2.19
13+800
14+700
15+900
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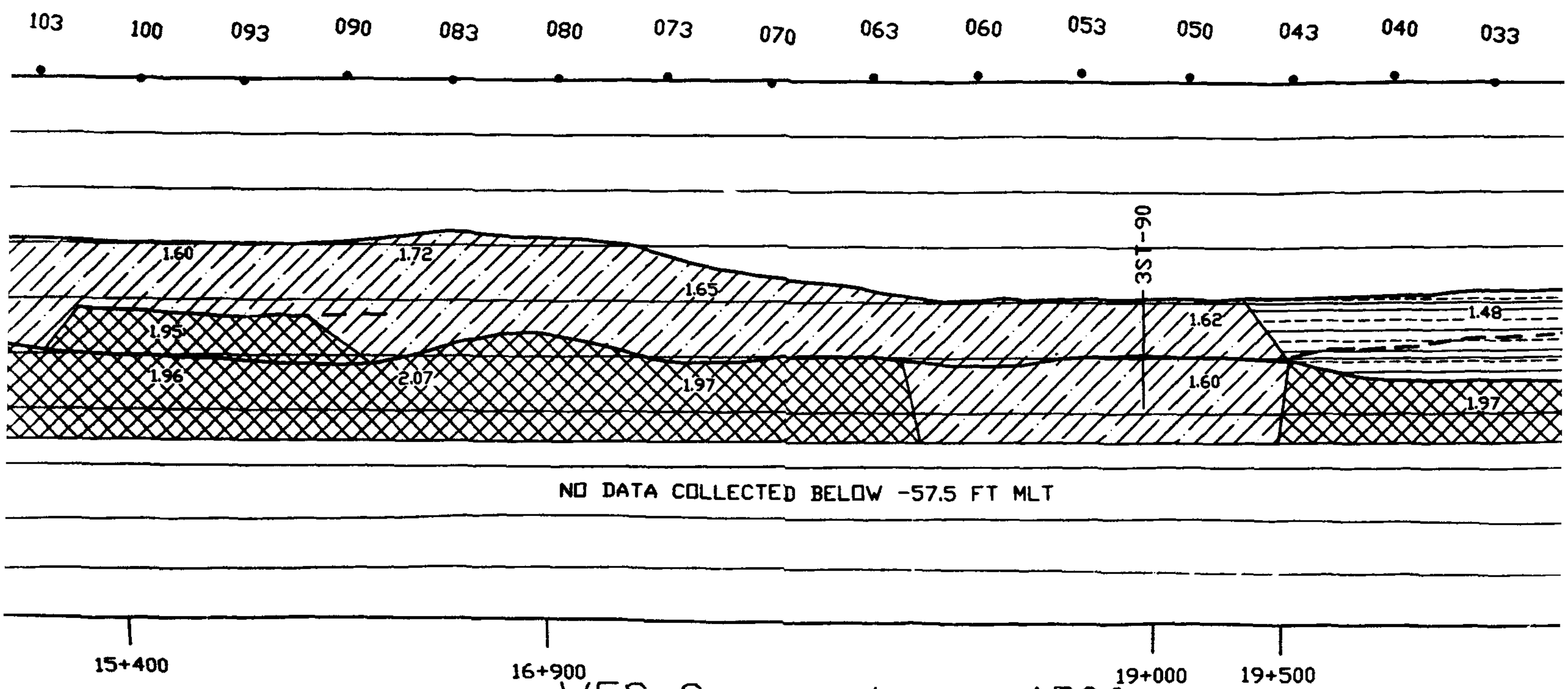

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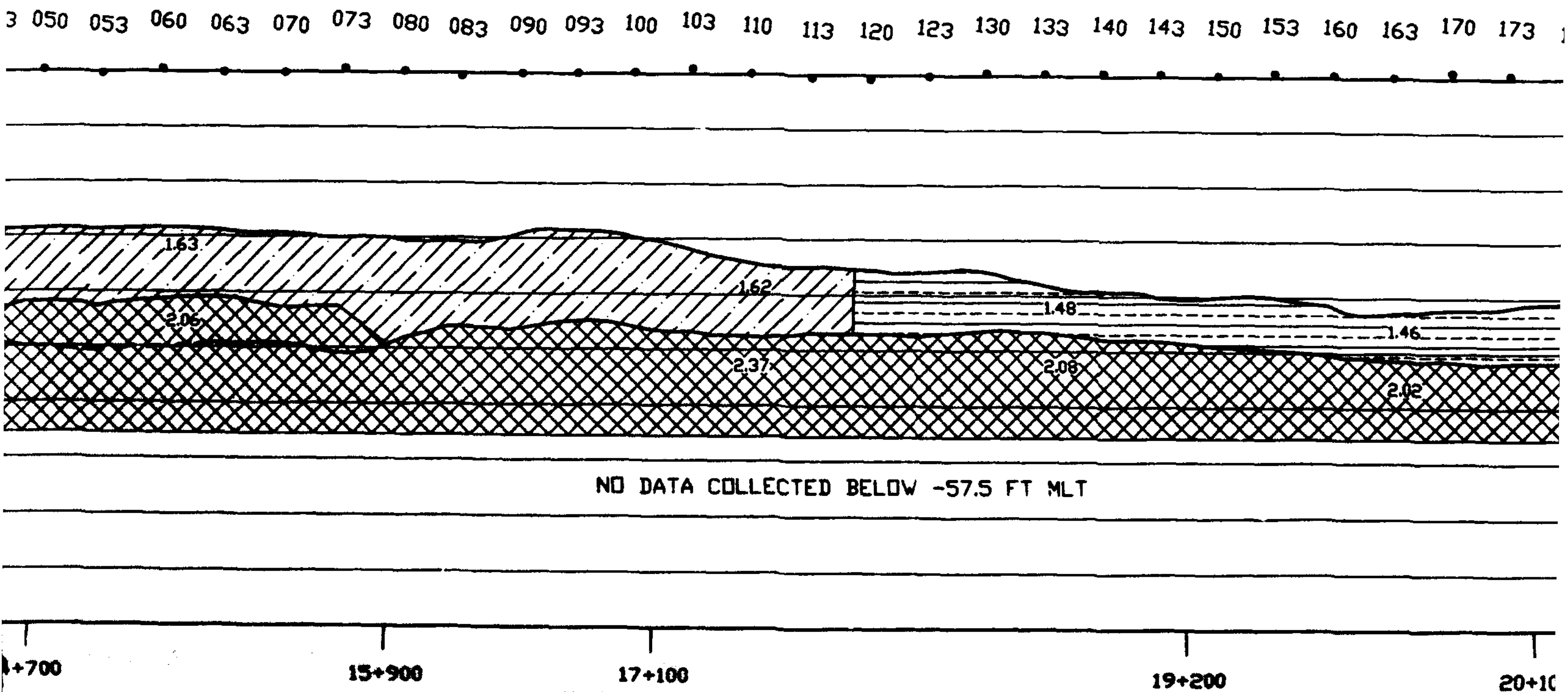
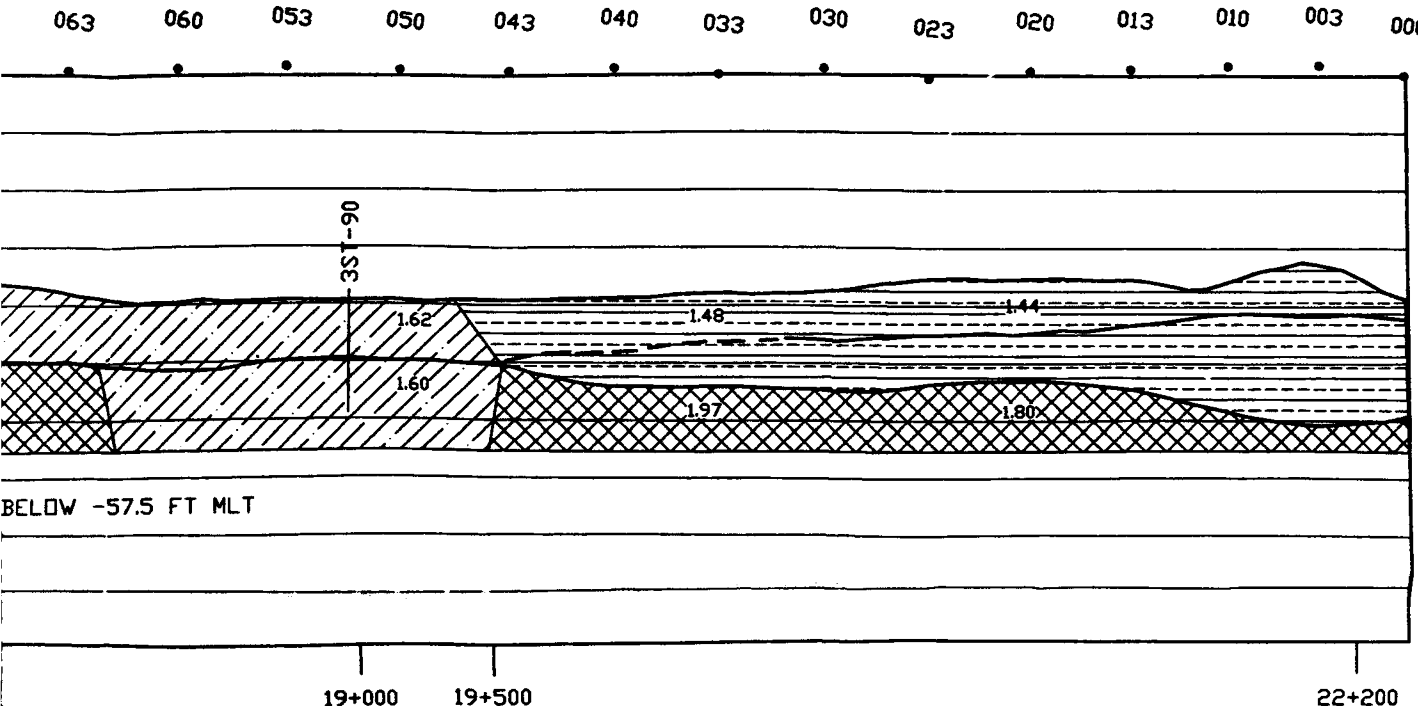
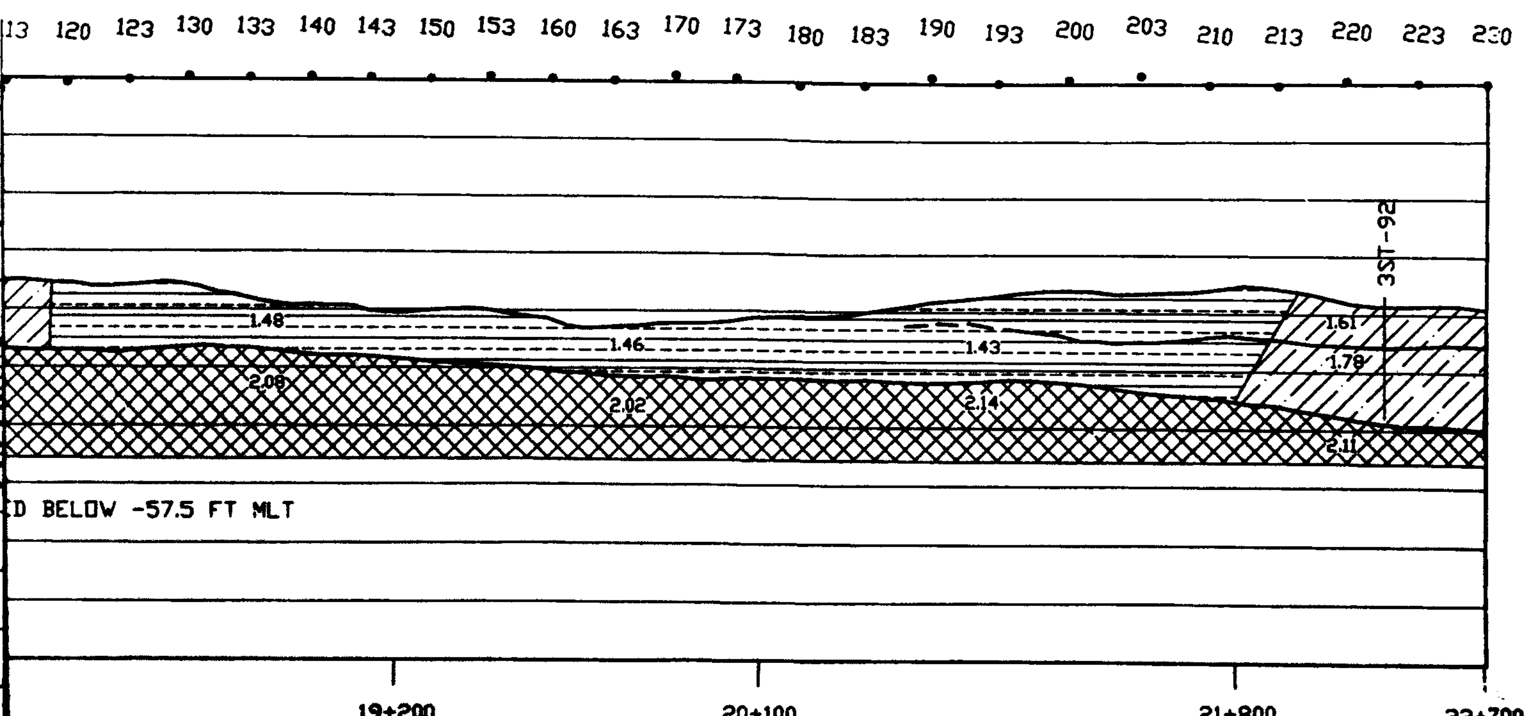


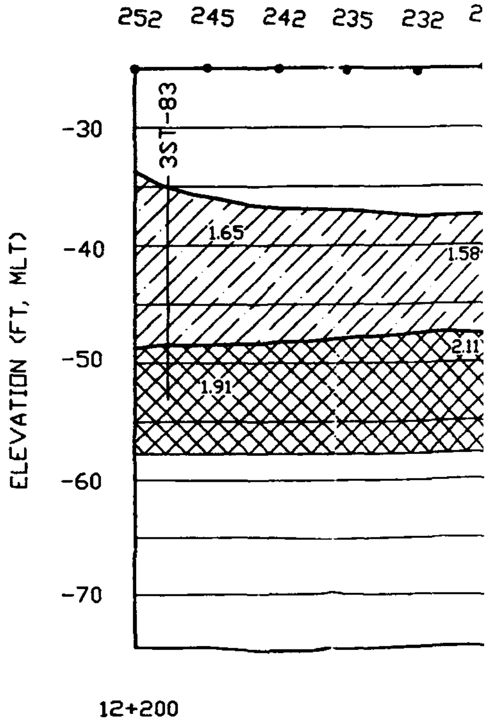
WES Survey Line: AP05



y Line: AP06



Line: AP05



DENSITY RANGES (g/cm^3)

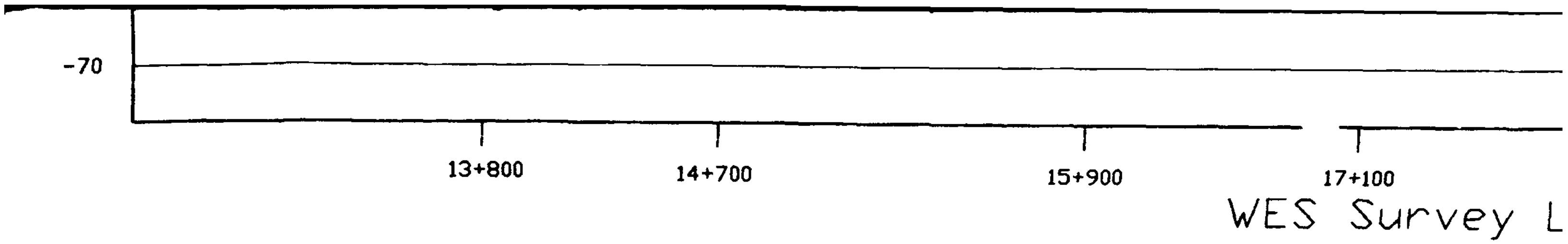
1.0 - 1.4

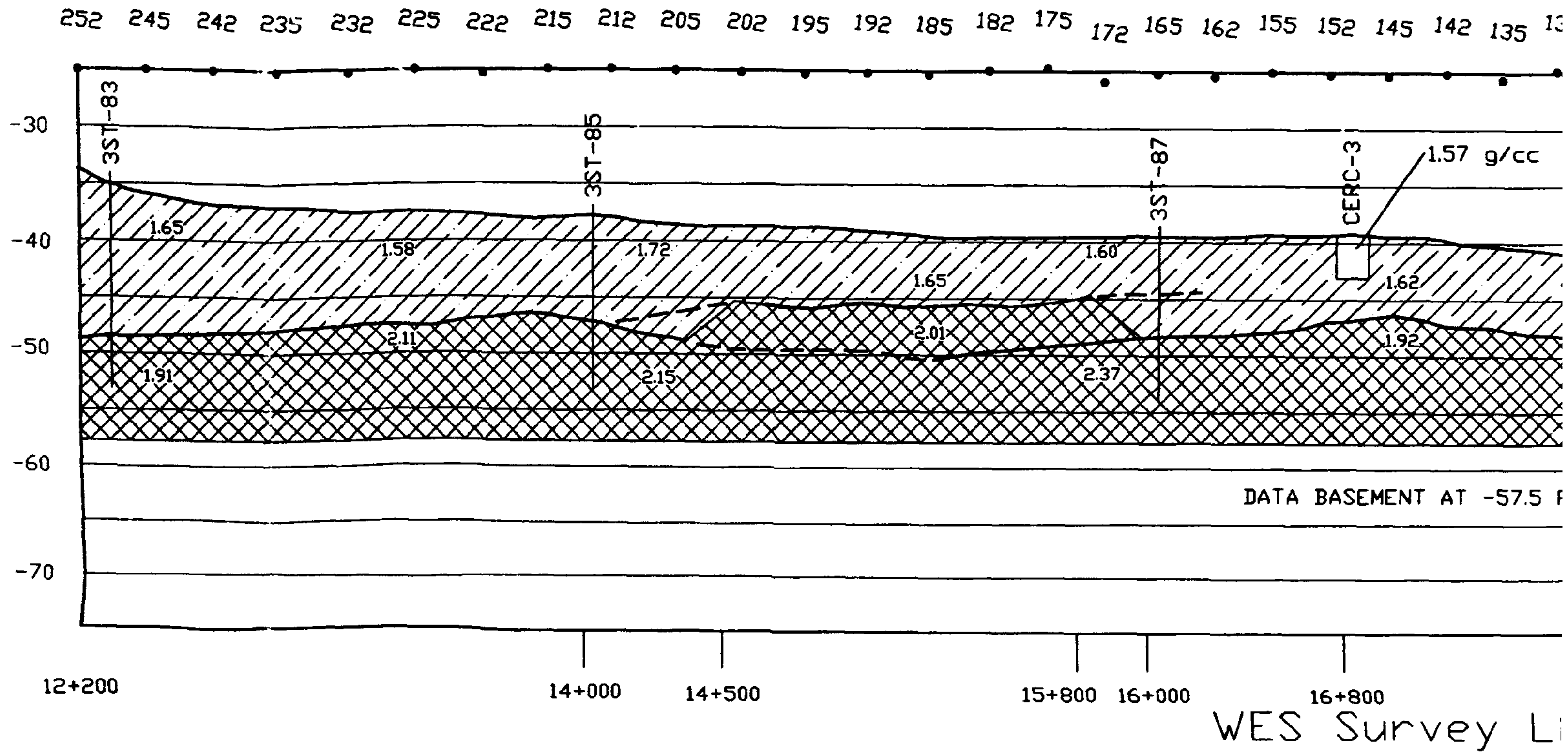
1.4 - 1.6

1.6 - 1.8

1.8 - 2.3 *

1.8 - 2.3 #



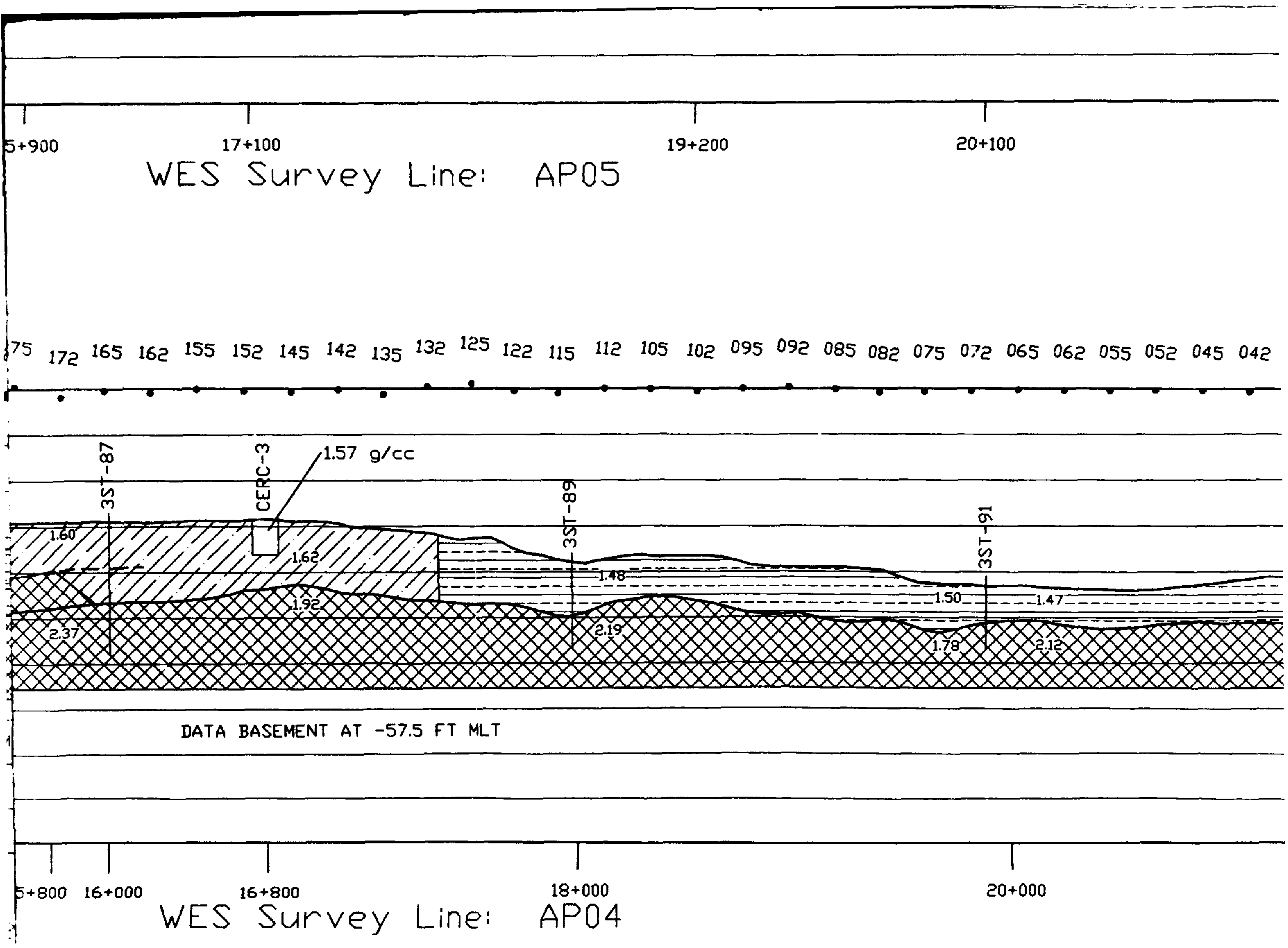


m^3)

NOTES

* Using CESWG Core Informa
densities are indicative of
sandy material.

\# Using CESWG Core Informa
densities are indicative of
moderate to stiff clays.



TES

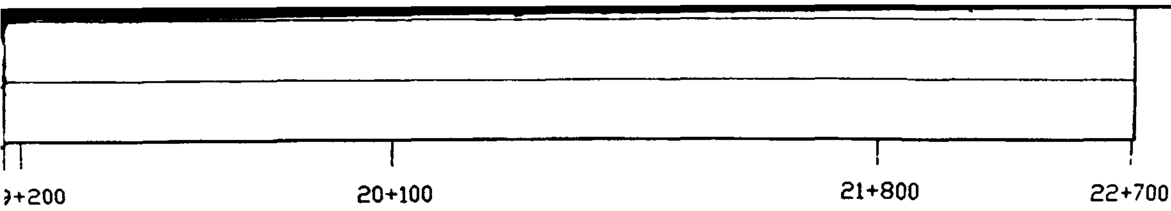
VG Core Information,
are indicative of
erial.

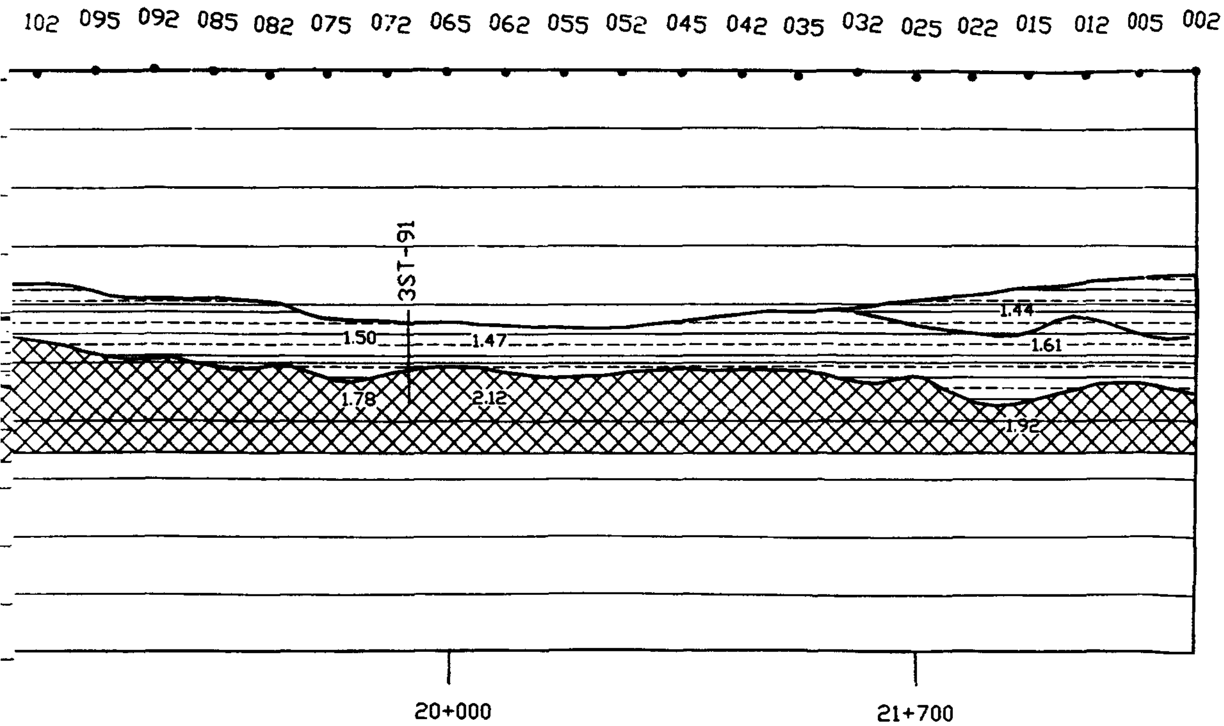
VG Core Information,
are indicative of
to stiff clays.

HORIZONTAL S

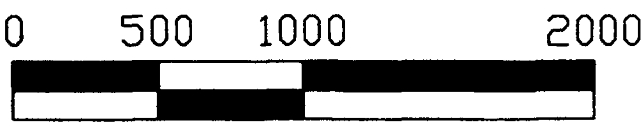
0 500 1000

VERTICAL EXAGGER



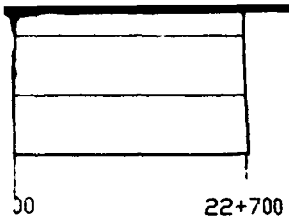


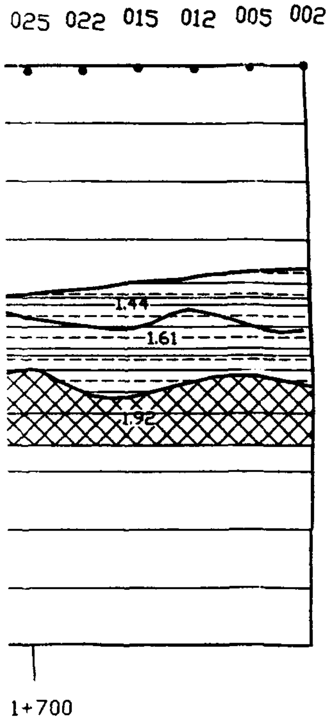
HORIZONTAL SCALE, FT



VERTICAL EXAGGERATION = x 40

DESIGNED BY KJS
DRAWN BY: JMV
CHECKED BY: KJS
SUPERVISED
SHREF.NO.



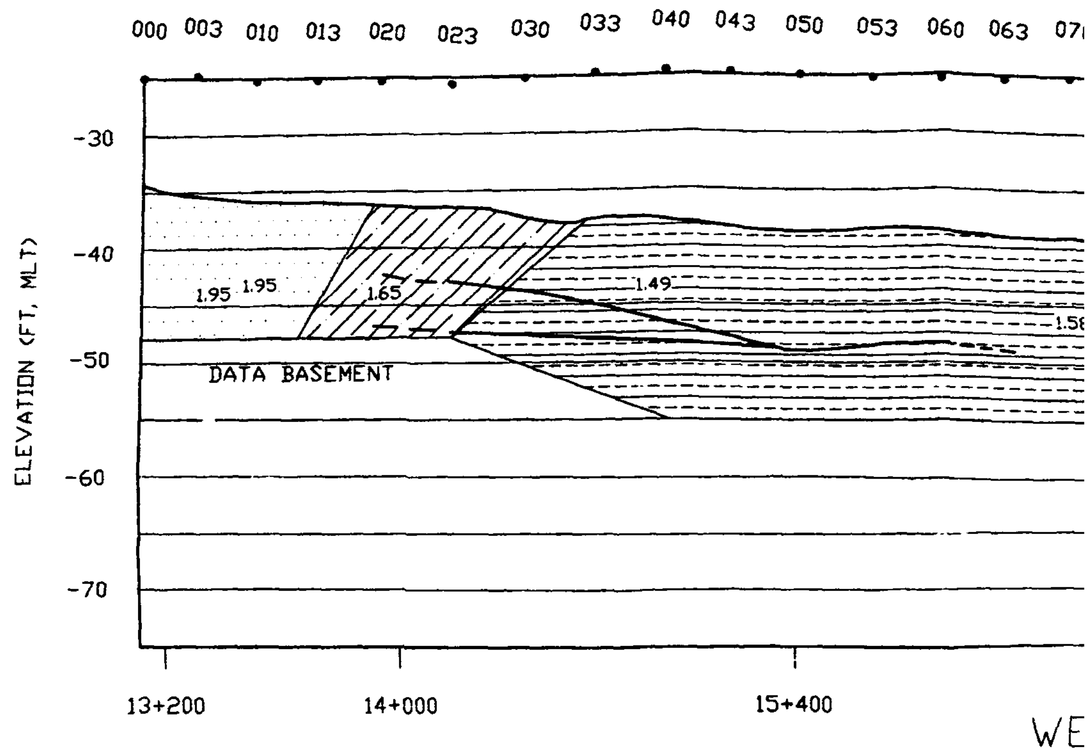


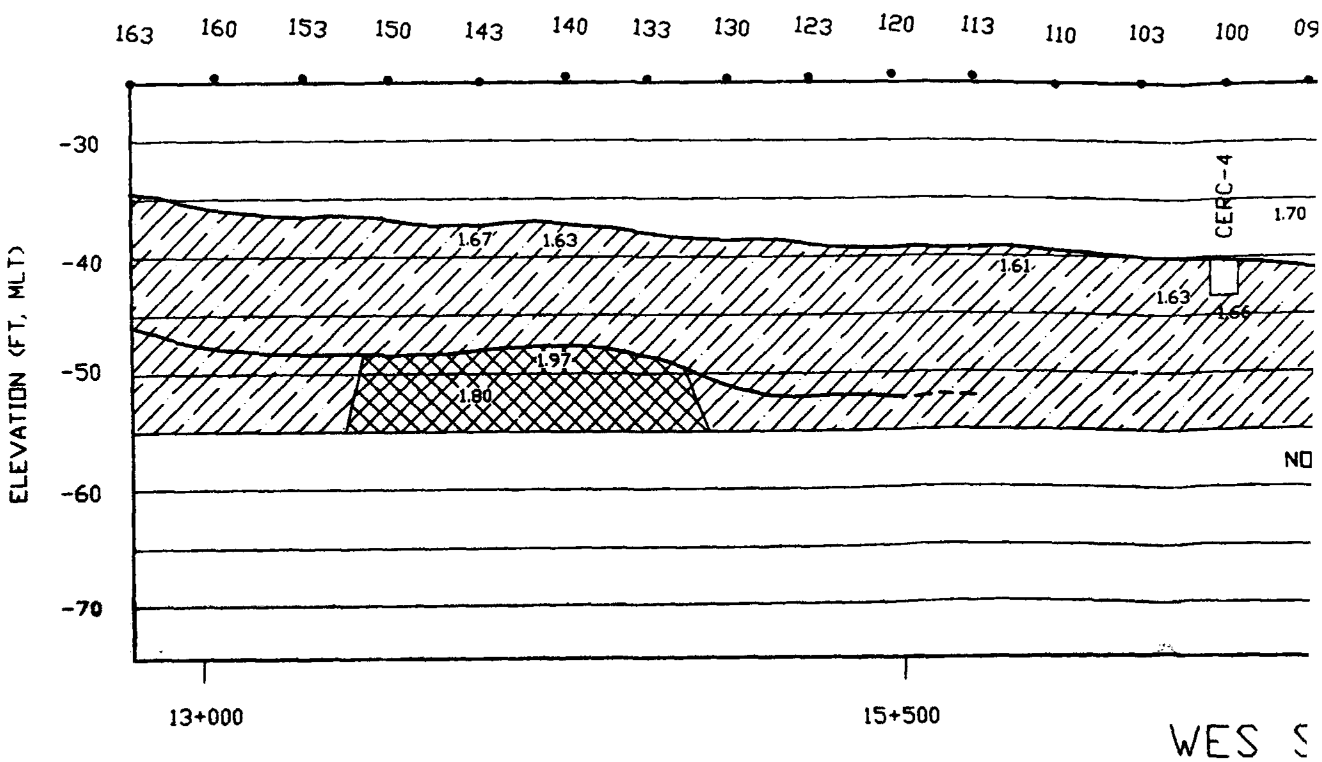
LE, FT

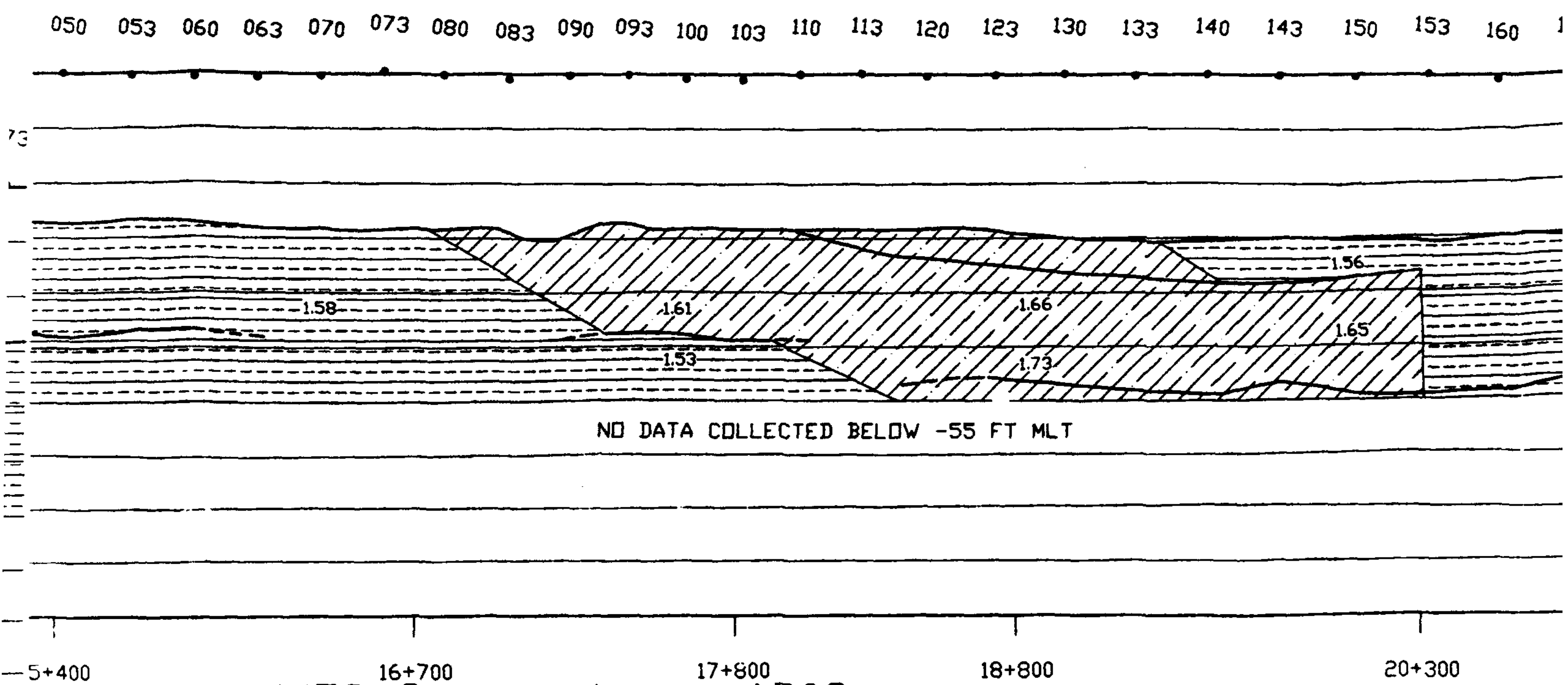
2000

ON = x 40

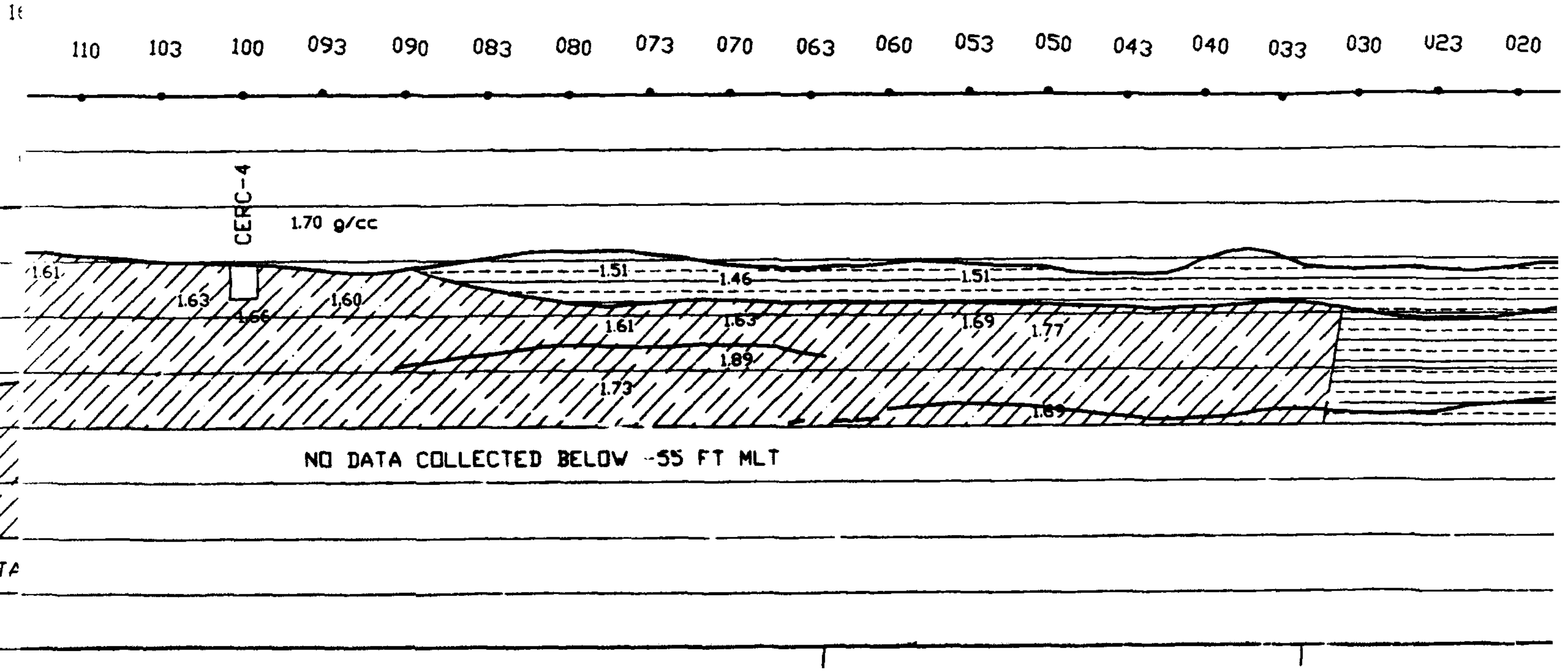
DESIGNED BY: KJS	WATERWAYS EXPERIMENT STATION CORPS OF ENGINEERS VICKSBURG MS		
DRAWN BY: JMV			
CHECKED BY: KJS	ANCHORAGE BASIN GALVESTON, TEXAS		
SUPERVISED BY:			
SH.REF.NO.	SPEC.NO.	SIZE	FILE NO. PLATE 4 DRAWING NO.
	SCALE: 1=600	DATE: 7 JUNE 1993	SHEET 4 OF 5


000 003 010 013 020 023 030 033 040 043 050 053 060 063
-30
-40
-50
-60
-70
ELEVATION (FT, MLT)
1.95 1.95
1.65
1.49
DATA BASEMENT
13+200
14+000
15+400
WE

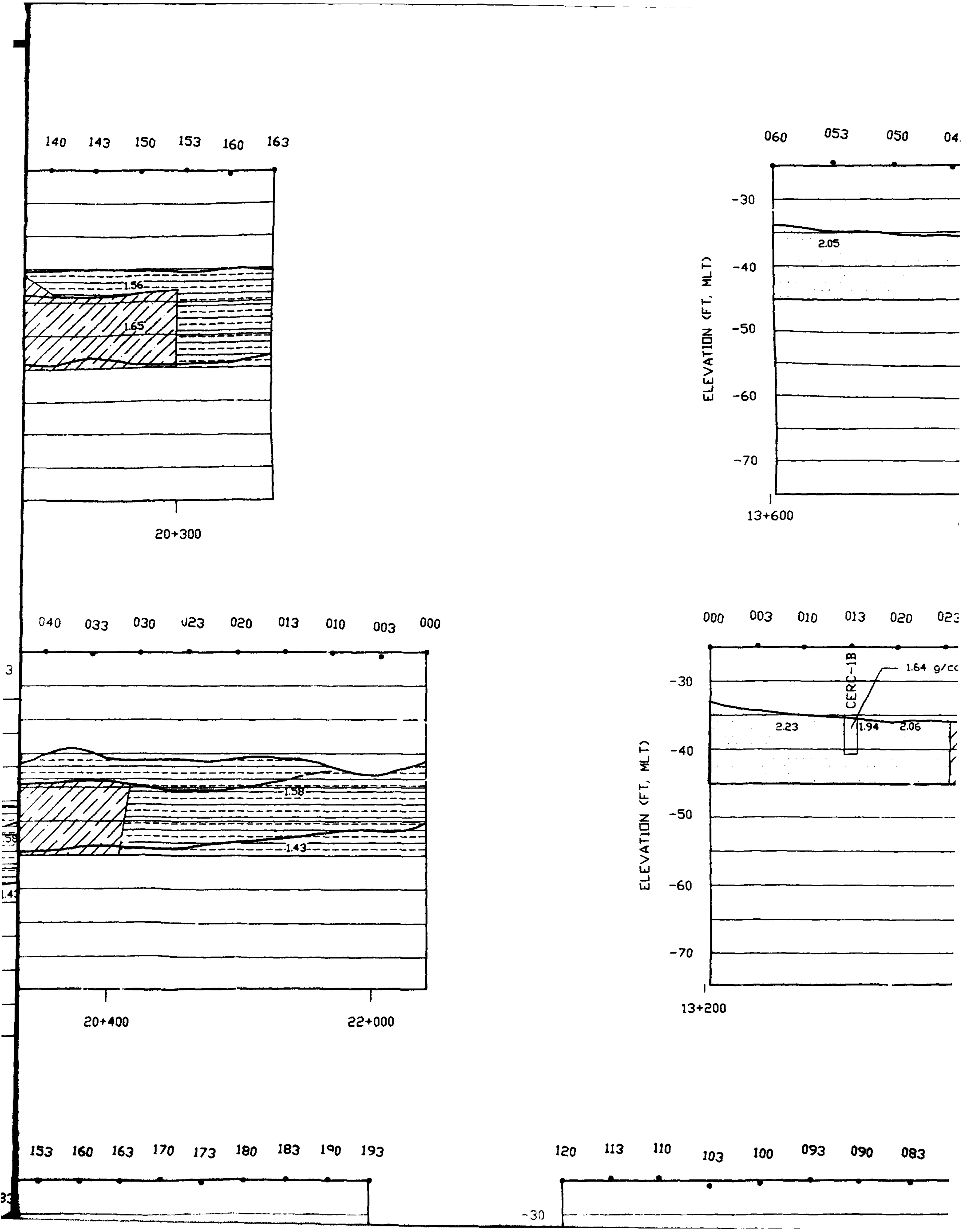

163 160 153 150 143 140 133 130 123 120 113 110 103 100
-30
-40
-50
-60
-70
ELEVATION (FT, MLT)
CERC-4
1.70
1.67
1.63
1.61
1.63
1.66
1.97
1.80
13+000
15+500
WES

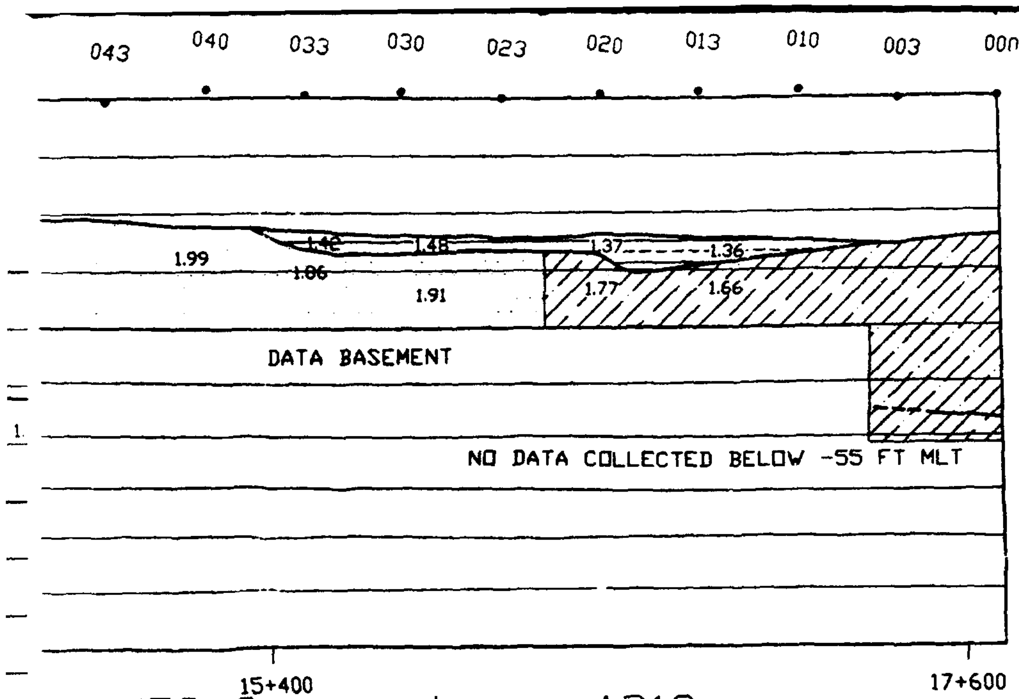


WES Survey Line: AP09

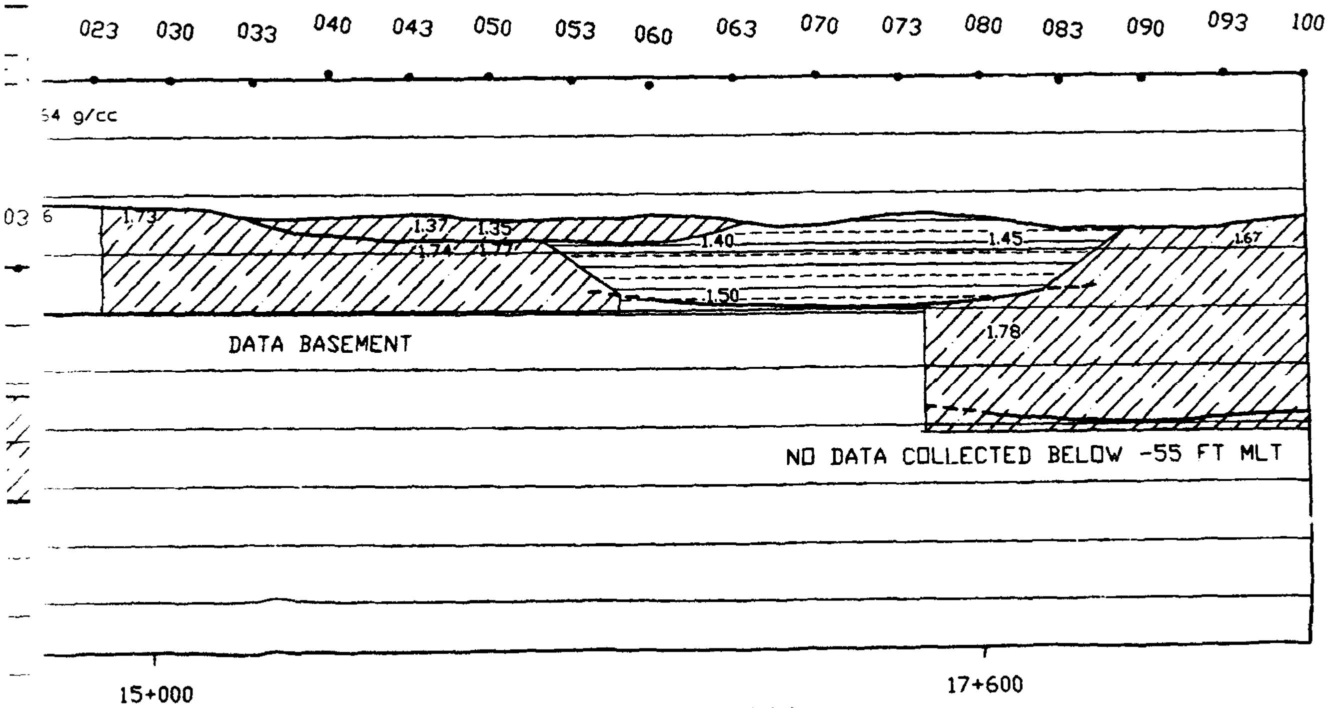


WES Survey Line: AP08

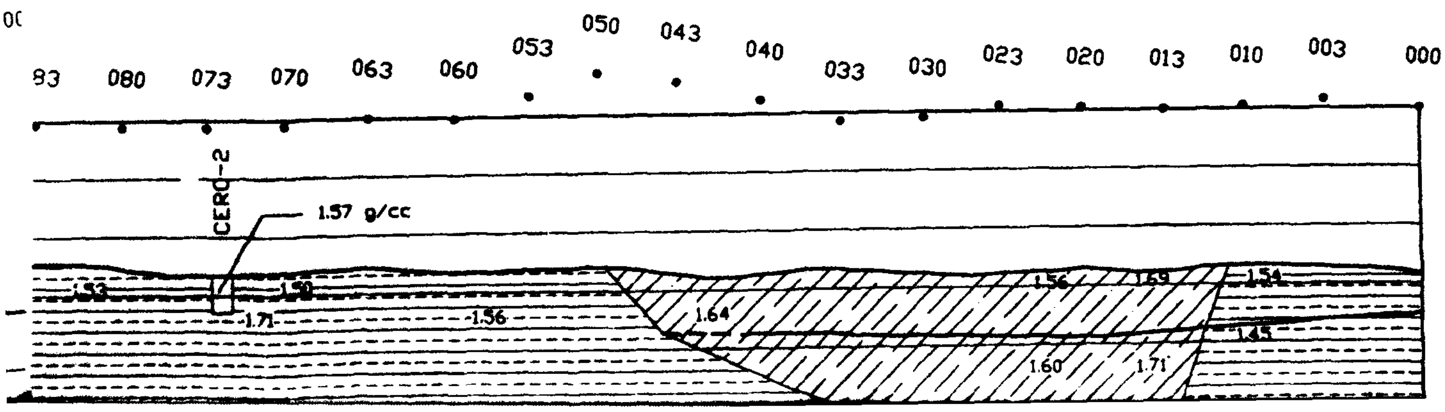

140 143 150 153 160 163
1.56
1.65
20+300
060 053 050
-30
2.05
-40
-50
-60
-70
ELEVATION (FT, MLT)
13+600
040 033 030 023 020 013 010 003 000
1.58
1.43
20+400
22+000
000 003 010 013 020
CERC-1B
1.64 g/cc
2.23
1.94
2.06
-30
-40
-50
-60
-70
ELEVATION (FT, MLT)
13+200
153 160 163 170 173 180 183 190 193
120 113 110 103 100 093 090 083
-30

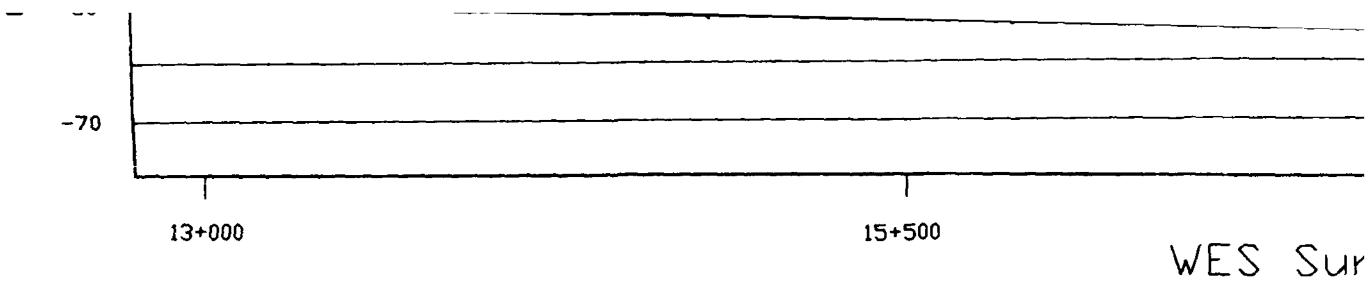


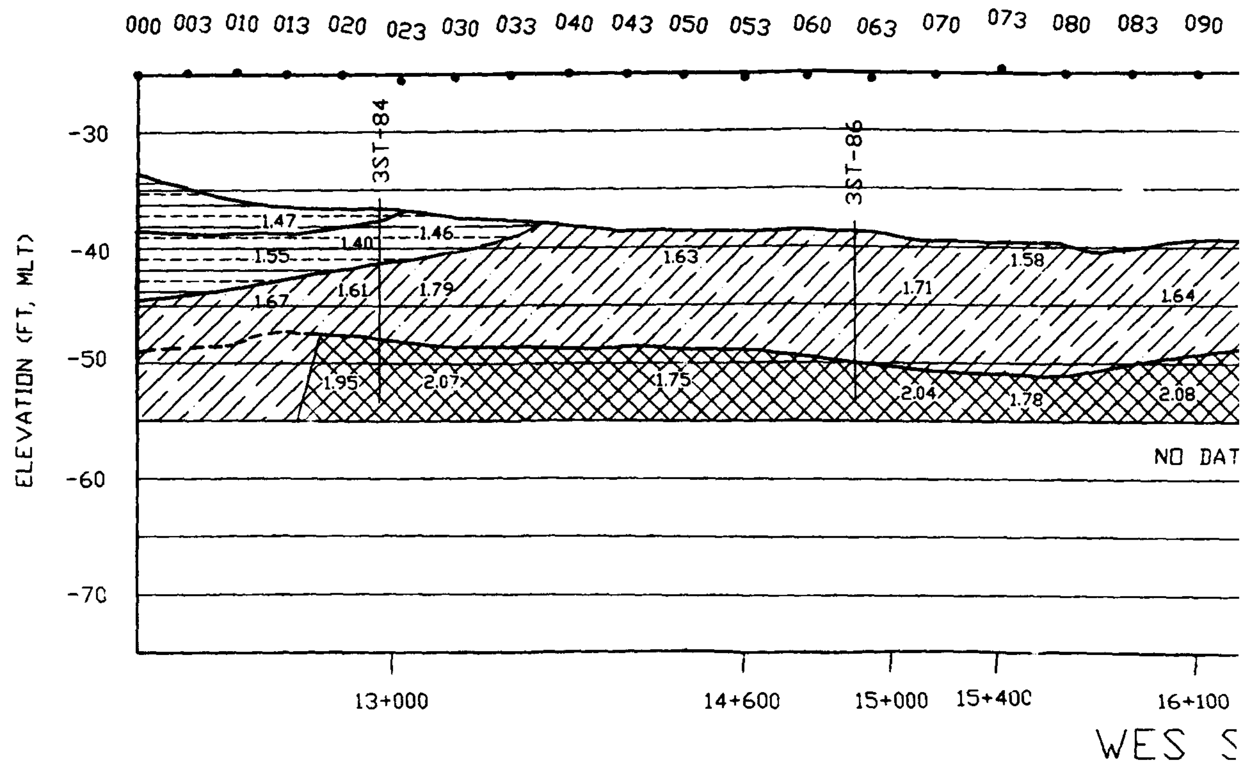
WES Survey Line: AP12

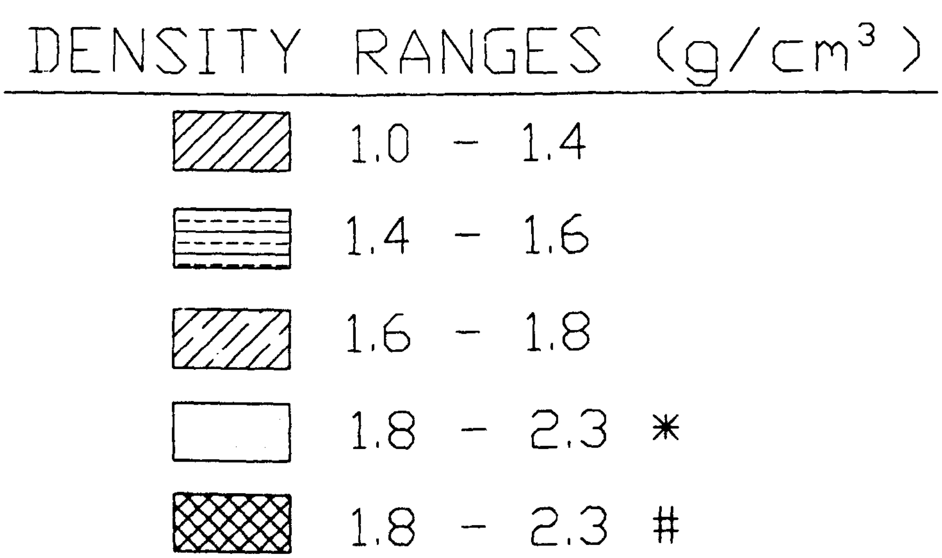


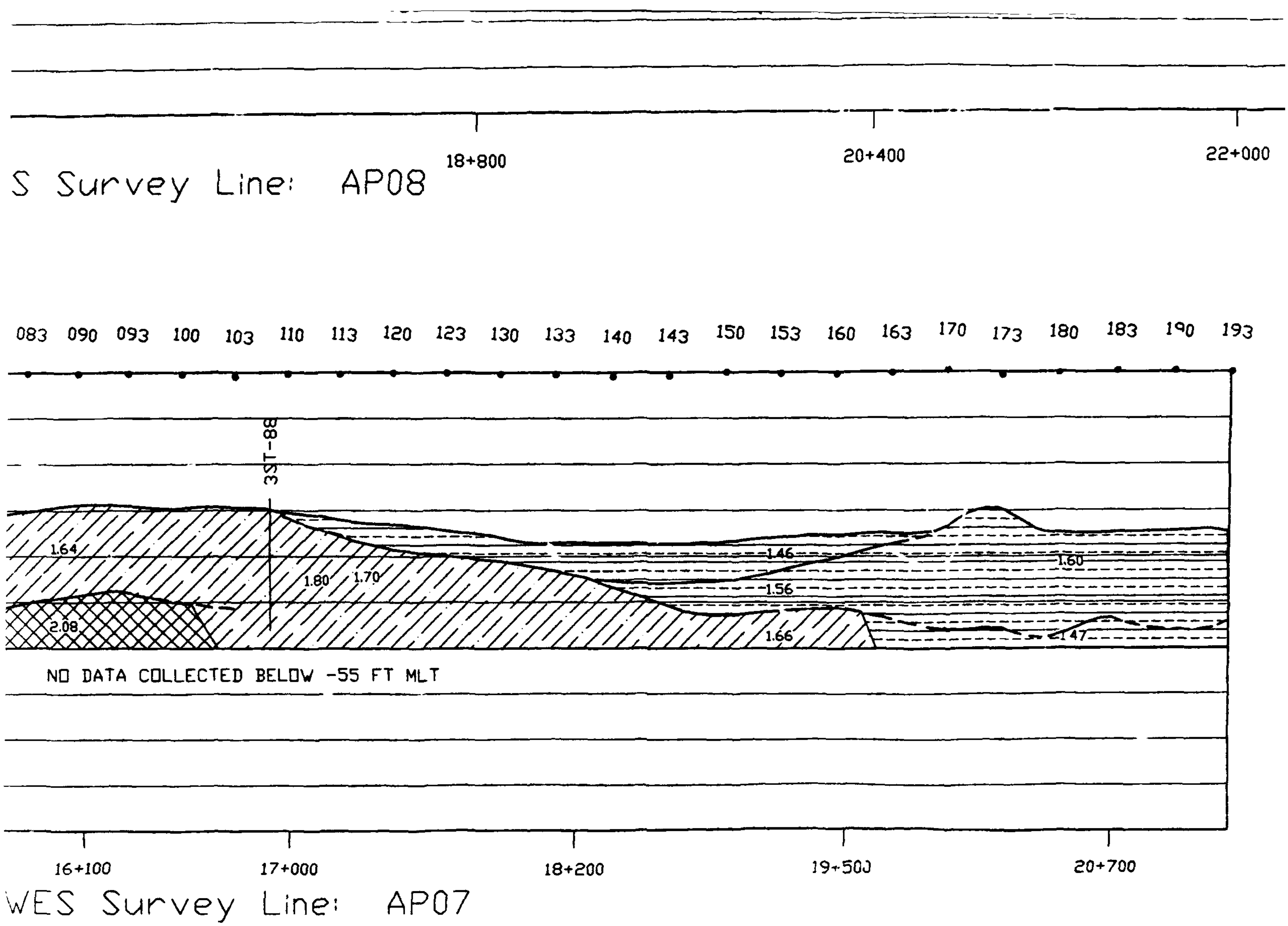
WES Survey Line: AP11




-70
13+000
15+500
WES Sur


000 003 010 013 020 023 030 033 040 043 050 053 060 063 070 073 080 083 090
ELEVATION (FT, MLT)
-30
-40
-50
-60
-70
3ST-84
3ST-86
1.47
1.40
1.46
1.55
1.61
1.79
1.67
1.63
1.71
1.58
1.64
1.95
2.07
1.75
2.04
1.78
2.08
NO DAT
13+000
14+600
15+000
15+400
16+100
WES S

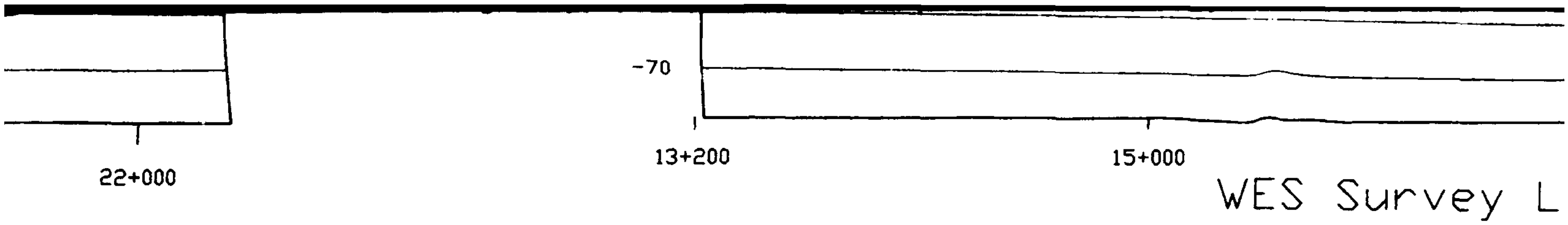

DENSITY RANGES (g/cm³)
1.0 - 1.4
1.4 - 1.6
1.6 - 1.8
1.8 - 2.3 *
1.8 - 2.3 #

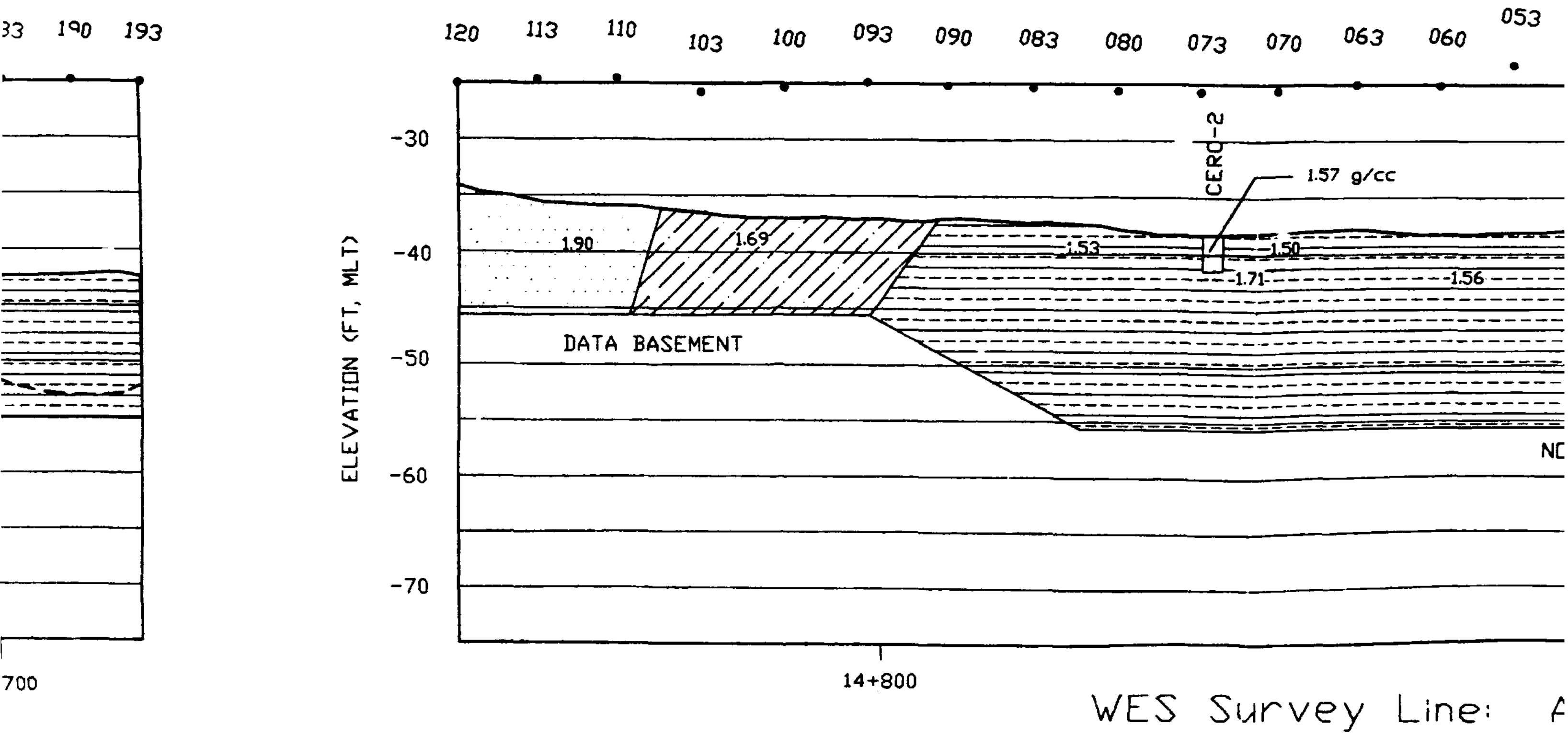


NOTES

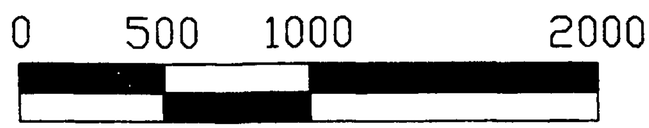
* Using CESWG Core Information, densities are indicative of sandy material.

Using CESWG Core Information, densities are indicative of moderate to stiff clays.

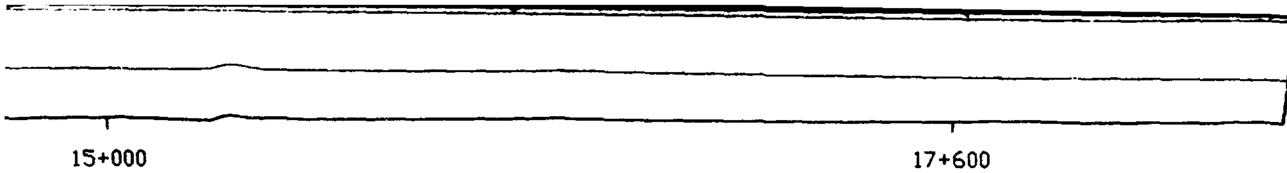




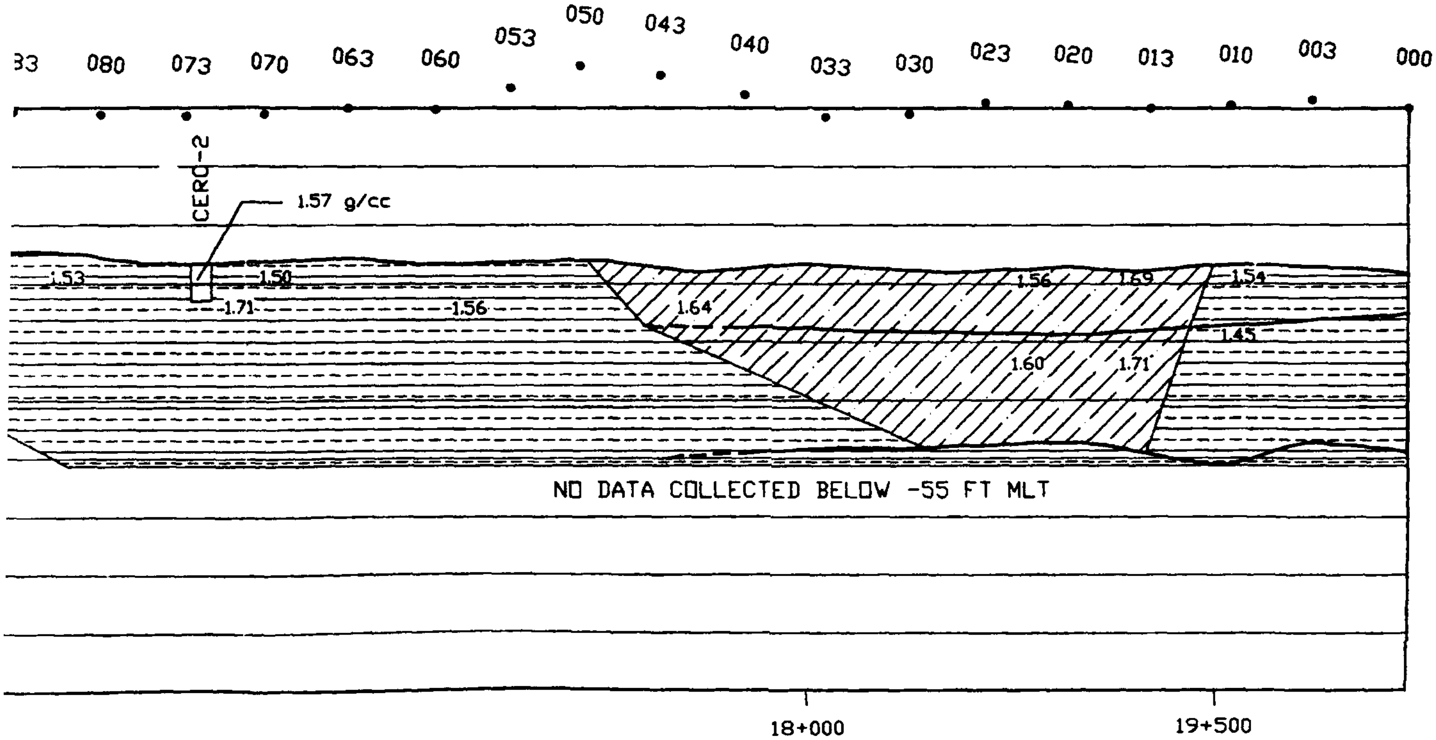
HORIZONTAL SCALE, FT



VERTICAL EXAGGERATION = x 40



WES Survey Line: AP11



WES Survey Line: AP10

ALE, FT

2000

ION = x 40

DESIGNED BY: KJS

DRAWN BY: JMV

CHECKED BY: KJS

SUPERVISED BY:

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG MS

ANCHORAGE BASIN
GALVESTON, TEXAS

SH.REF.NO. | SPEC.NO. | SIZE | FILE NO.

PLATE 5

DRAWING NO.

SCALE: 1=600 | DATE: 7 JUNE 1993 | SHEET 5 OF 5